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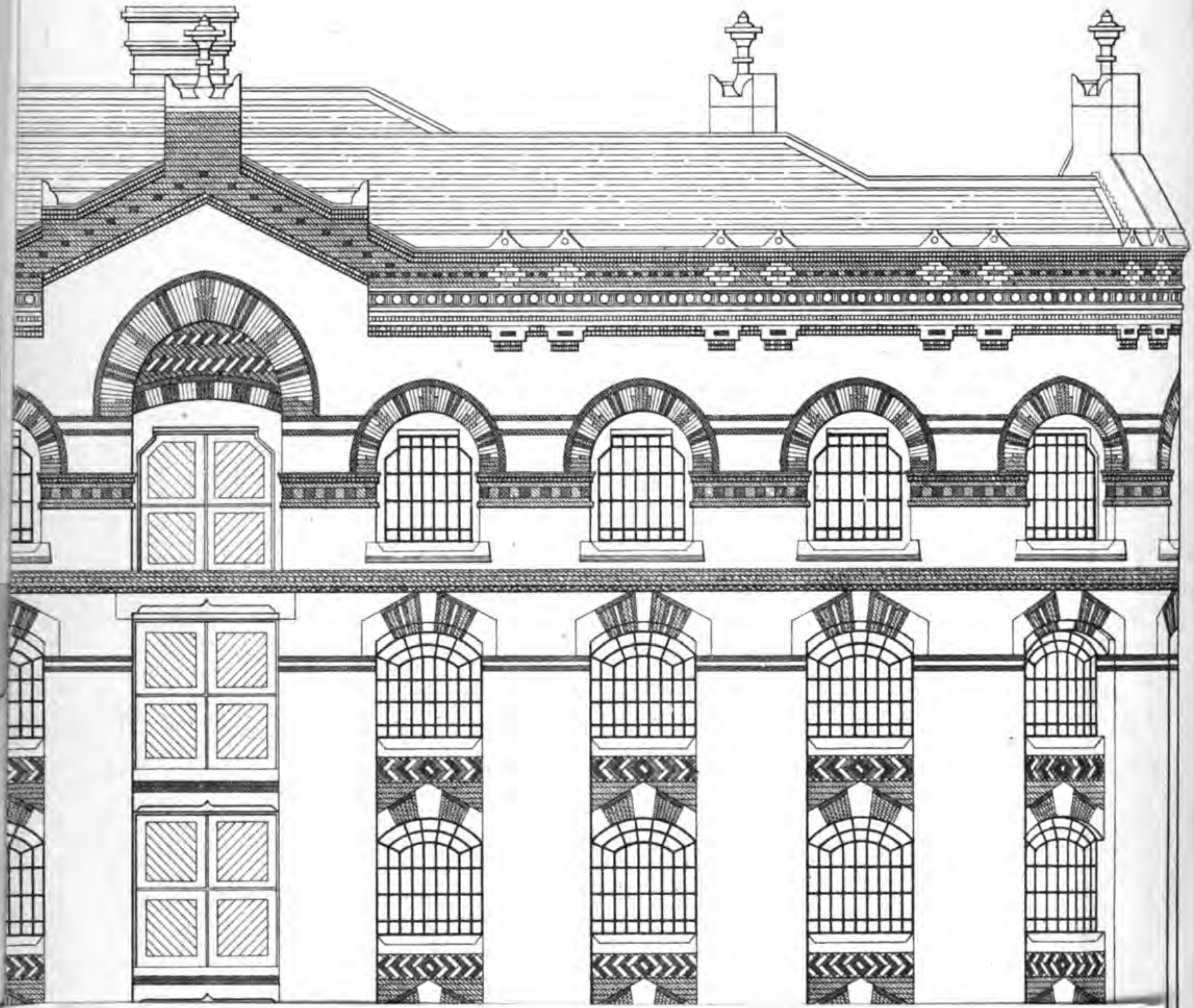

THE

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THE MANAGEMENT OF TOWNS.

Whenever men have departed from that simple mode of life in which each family provides within itself for the safety and the wants of its members, and have gathered together in considerable numbers upon a limited area, the necessity for sanitary regulations of some kind has soon made itself disagreeably evident. We have proofs of the existence of such regulations among the ancients, both in written records and in those remains of works for drainage and water-supply which time has spared. Yet there are no chapters in history more sad than those which record the warnings by which men learnt slowly to protect themselves from the effects of overcrowding, and the ready forgetfulness which a season of impunity has always induced. In our own country, from the time that the growth of towns began to be fostered by grants of privileges, the footsteps of pestilence are everywhere traceable, and even such smaller settlements as the monasteries that were planted in the open country had not a complete immunity. As the population increased, which it did, in spite of plague and the milder scourge of war, *dirt*, in all its forms, increased with it, and held its place, as it too often holds it now, by prescriptive right; where possible, it was hid from sight, and its appeals to the sister sense were neglected, or, when on a smaller scale, were quieted with the perfume of aromatic herbs. From time to time, however, efforts were made to check the increasing impurity of the soil, the water, and the atmosphere, but no attempt to grapple with the evil upon a large scale had much chance of success. The mass of ignorance and prejudice that had to be overcome was usually too inert to yield to the efforts of the few, who saw by a dim and uncertain light the nature of the mischief, and its cure. The power of meddling with private rights, and rating property for public purposes, was not easily wrung from men who did not fully believe in the urgency of the case, and whose interests were heavy in the scale of unbelief. Yet, in some cases of strong necessity, special powers were in process of time obtained by public bodies to make better provision for the health of towns, and since the commencement of the last century, such powers have, in numerous cases, been obtained by the troublesome and expensive process of private Acts of Parliament for the drainage, cleansing, paving, lighting, and watching of particular towns, for supplying them with water, and for other useful objects. These are the Improvement Acts which, until lately, were the chief means by which the inhabitants of a town might obtain, by common action, the advantages above enumerated, and enforce upon the thoughtless and ill-disposed some regard for the public convenience. After a while, advantage began to be taken of the experience that had been gained in the working of the older acts, and a degree of uniformity exists amongst those of later date; the legislature being generally ready to grant to new applicants such powers as had been found useful in other cases, and the applicants being willing to burden themselves with charges that were borne elsewhere. The rapid growth of towns in the present century tended, of course, to make the adoption of new arrangements a matter of evident necessity. At length (coming to within about twenty years of the present time) it was deemed advisable to pass a series of public acts, which might be easily applicable to all populous places, and would regulate their management upon such a system as was then thought best for the purposes had in view in the old local and private acts. This end was not obtained at once, but, beginning with the year 1847, we have a series of acts, such as the Towns Improvement, the Police, and the Markets Clauses Acts, the Public Health Act, the Nuisances Removal Acts, the Local Government Act, and some others applying to England generally. In London, "the City" has its special act, and the surrounding districts are regulated by the Metropolis Local Management Act, 1855, and its amendments. With some of these the Lands Clauses Consolidation Act is incorporated for certain purposes; and the whole form a body of laws which, however imperfect they may be, are a vast stride in the direction of health, comfort, and convenience.

It will be understood that these acts are intended to provide for the management of towns, not only in matters which have a direct bearing upon the health of the people, but in matters which affect their security in person and property, and in other matters needing to be regulated where dwellings are closely packed, and traffic is thick upon the streets: such matters as are not provided for by laws affecting transactions between one man and another, or such as from their nature ought to be dealt with before they produce materials for private litigation. Amongst these are interferences with, and obstructions of, the public way, and modes of using private property so as to produce danger to inmates, neighbours, or passengers. But all these are more or less connected with those which bear more directly upon health, for even when they do not involve danger to life or limb, it is difficult to say that anything which interferes with the convenient transaction of business, and renders the performance of necessary duties troublesome or impossible, does not also tend to destroy life by diminishing the means by which we live. These are therefore properly made the subject of enactments which place their regulation under the same local authorities as have to deal with matters more directly affecting health.

In determining the measure in which the powers granted by the legislature ought to be exercised in any particular case, opinions will naturally differ to a considerable extent. Granting that perfect arrangements for drainage, cleansing, lighting, &c. are desirable, and are those only which work effectually at all times, every defect being at once discovered and remedied, it will follow that every abatement from this standard is, to the extent to which it goes, a failure; and, in effect, that all arrangements hitherto adopted are failures. But, as in most other matters, the provision must be regulated by the extent of the evil existing or apprehended, the test of efficiency in any particular arrangement being that it answers its purpose, and is good of its kind. In thinly-peopled districts it may happen that defects will exist without producing the evil consequences which would result if the population was greater. But the poverty of a district is too frequently allowed to form an excuse for neglect in sanitary matters, when, in fact, it is a reason for increased vigilance and care. In such a district there are improvements which, as they do not act upon the public health, may be postponed without injury; but those which tend to check the spread of disease should be effected, whatever the cost may be. On the other hand there are, in all towns, parts where the improvements needed will be chiefly such as conduce to the convenience of residents and travellers, and where the rateable value of the property will justify a large expenditure for these purposes.

Many matters of detail are to be considered in judging of the state of a particular town; but after making every fair allowance for difficulties, local or otherwise, there is reason to believe that in very few places is there any effectual carrying out of such sanitary arrangements as are in the power of the local authority, and are of admitted necessity. We see proof enough of the tardiness with which the most important improvements are adopted, and of the effect of private interests in counteracting measures of public benefit. Powers that are conferred upon the local authority are exercised timorously; contracts made by them are, either from insufficient foresight or from some other cause, left short of complete fulfilment, while duties that have been cast upon individual inhabitants are in many places habitually neglected. To speak only of such things as are immediately under the eye, the roadways are formed in a manner, and of materials, that encourage the production of dirt, if they do not assist to produce it; they are not thoroughly cleansed, either in wet or in dry seasons, while that portion which the inhabitants are bound to clean is neglected with impunity. They are thereby encouraged to make the roadway a place of deposit for the rubbish which they are equally bound to deposit elsewhere. Complaints of the lighting and supply of water are also frequent and well-founded.

For these, and most other evils of the same kind, there are remedies provided in one or other of the sanitary laws, and these remedies should be applied with firmness and moderation, both on account of the public health, and because a great part of the enjoyment of a town, and the value of the property in it, depends upon the state of cleanliness and comfort in which it is maintained. The beauty of fine streets and costly buildings is destroyed by neglect, even in trivial matters; as in some cities whose architecture is of the highest class, the visitor is teased with an ever-present sense of nuisance but half concealed, that destroys the charm of their beauty, and lowers their grandeur to the common level.

Wherever the state of things which has here been indicated exists—and there are parts of the metropolis, as well as provincial towns, against which the charge is frequently made—a heavy responsibility lies at the door of those in whose hands the power of local government has been placed. It may be that they do not see the importance of the duties that are cast upon them, or that they feel bound to protect the pockets, rather than the higher interests of the ratepayers who placed them where they are. In any case, it becomes the duty of those who can promote the action of any part of the machinery by which towns are governed to use such means as are at command, and seem likely to produce useful results. We regard the present time as favourable for drawing the attention of our readers to those portions of the subject which are in their province, and pointing out means by which they may help to forward those reforms for which there is too much room and too much need.

In the Acts of Parliament to which reference has been made, power is given to appoint an officer, who is therein called the surveyor. He should be a properly educated surveyor or engineer, of experience sufficient to qualify him for the important duties he has to perform, and for advising the local authority upon practical matters within his department. The number of men belonging to these professions who are so employed, is large, and is likely to increase. The appointments are in some cases lucrative, and will probably increase in value as their importance becomes more strongly impressed upon the public mind; for it would hardly be too much to say that where the local board is not itself obstructive, the proper action of the whole machinery created by these sanitary acts depends mainly upon the efficiency and the influence of this officer, as their responsible adviser, and the medium by which their works are carried out. From the constitution of these boards, the members of which change frequently, and are usually elected on other grounds than that of special fitness for dealing with sanitary matters (though their business qualifications may fit them for deciding upon such matters, when they are properly laid before them), there is constant need for experience in their officer, and for knowledge of the experience that has been gained in other towns. He is bound to be provided with information of this kind, and, working in harmony with the medical and other officers, to carry out the orders of his board with economy, particularly as the bulk of the money raised by rates is expended through channels over which he has control. In the interest of those who fill this office, as well as of all who are affected by the good or ill management of towns, it is our intention to give, from time to time, such information as we can obtain with regard to the practice of those local authorities which, from the importance of their district, or from their lengthened experience, may be supposed to afford the best examples for study. The materials available for this purpose are of various kinds, and without interfering with matters of a private nature, it will be possible to obtain from official documents, and other trustworthy sources, a large amount of information that will prove serviceable in the various departments in which the town surveyor is called upon to act.

ON THE MECHANICAL CONDITIONS OF RAILWAY WORKING TO PREVENT DESTRUCTIVE WEAR AND RISK.*

By W. Bridges Adams.

This is a subject not of mere local or of class interest. In days gone by, when a man was by the mass of cockneys esteemed a traveller if he had been to Gravesend and back, it would have interested but a very few to discourse on the means of transit, but in the present day, all men, women, and children, have become locomotists, getting back to a state of nature, like the birds and wild animals, and no longer confined to the spot on which they are born and bred. And a very good thing it is for themselves and general humanity, for they thereby become educated, not in the sense of book learning, but in the sense of knowledge of men and things, expanding their thinking faculties with the more healthy growth of their bodies. We increase thereby the number of men and women, instead of mere human animals, and we increase also national power, which is not to be measured by animal units, but by the mass of intelligence, health, and physical strength—in short, vitality. It is better to soar like birds, than to burrow like rats; and though we cannot soar above the earth with guiding power like birds, we contrive to skim along the surface, though not quite so fast, and do not yet see our ultimate limit to speed accompanied by safety. We are fast becoming a nation of mechanicians, and each man's strength is as the strength of ten, as fast as he acquires a sound body for a sound mind to dwell in. The subject is possibly a dry one in its details, but out of these dry facts must come the growth of progress; and this must be the writer's apology for dwelling on them, though in as succinct a mode as language will permit. In criticising any subject it is but natural that the critic should devise plans for amending that which he deems wrong, and in so doing the writer would deprecate any appearance of egotism in dealing with his own plans.

In vehicular transport the contact between the vehicle and the road it moves on, may be of three kinds, sliding or sledging, rolling, and a compound movement, partly sledging and partly rolling. The sliding movement may be converted into rolling by the application of water, oil, or unguents, the particles of which form rolling bodies between the vehicle and the road, as with the ship on water, or with the wine sledges used in Madeira, where the driver sluices the road beneath the sledge runners; or with the winter sledges of cold climates, where frozen surfaces supply rolling particles. If actual contact between the moving vehicle and the road take place without the intervention of rollers or lubricants, destruction must ensue by abrasion.

Where no means exist of supplying lubricants to the road surface, the next process to ease the sledge is to place rollers under it. If the rollers be true cylinders, and are not fixed to the sledge, and the movement be in a straight line, there will be absolute movement without friction. If the rollers be fixed to

* Paper read before the Society of Arts.

the sledge, by axles passing through them and bearing the load, the friction will be transferred to the surface of the axle from the surface of the road, and will be greatly reduced if the oil or unguent forms an efficient lubricant. If the roller bears on the road through its length, and be a true cylinder, it will move forward in a straight line. If it be of a conical form it will move in a curved line corresponding to the cone. But if two coned rollers be fixed to the sledge with their axles parallel, the movement will be partly sliding and partly rolling, with great friction in a straight line. If the two coned rollers be not parallel, but are arranged with their axles in converging lines corresponding to the cones, the machine will move in a circle, the centre of which will be the point where the converging lines intersect each other.

The ancient Greek and Roman cars were mounted on rollers; *i.e.*, a pair of wheels connected by a fixed axle running between thole-pins, such as up to the present day we see in the wine cart of Portugal and parts of Spain, which are unfitted to turn corners and make so fearful a squeaking when running out of a straight line as to give rise to the jest that they are so ordered to give warning to the custom-house officer in case of smuggling. Double-roller cars also existed, with fixed parallel axles, and this faulty mechanism was probably one cause why the old Roman roads were made in straight lines, as it was easier for such cars to run up hill than to follow curves. Even supposing the case of four-wheeled cars with two wheels running independently on their axles, these cars could still only run in straight lines as long as their axles were rigidly parallel; and in England it was only during the reign of Queen Elizabeth that what were called "turning carriages" first existed, *i.e.*, with a mechanism that perpermitted the axles to depart from their fixed parallelism to pass round curves.

When railways, as distinguished from tramways, were first commenced, the faulty mechanism of the early classic cars was resorted to as a cheap structure—cheap in first cost. Wheels proper were ignored—*i.e.*, wheels running independently on their axles—and rollers were used, *i.e.*, two wheels fixed to a shaft or axle, which revolved with them in thole-pins, or what are now called horn-plates. And, whether two axles, or three or more were used, they were always rigidly parallel. And this is the common practice in England to this day.

What are called tramways are formed of flat plates of iron, with rising edges to keep the wheels in track. Ordinary wheels, revolving independently on their axles, were used on them. Their mechanical disadvantage was that dust and dirt accumulated on the horizontal plates, and the wheels rubbed hard against the rising edges as against kerbstones, and caused much friction. Opinions are divided as to the origin of the term tramway, whether derived from an originator named Outram, or from the word "trammel," to curb or guide. The term "platelayer," on railways, is evidently derived from the original tram-plates. On railways proper, what is called the edge rail is used, in which the increased depth gives greatly increased strength to support the load, and at the same time dust and dirt have little chance of remaining on the rails. But to keep the wheels on, the rising ridge or kerb of the tramway is transferred to the wheel in the form of a flange. It is clear that vehicles with fixed wheels and parallel axles are only adapted to move in straight lines. If the axles were converging, the vehicles would only move in curved lines. But there is another common condition. a result of faulty workmanship—parallel axles not at right angles to the line of traction; in this case the machine becomes a sledge under all conditions, with the wheel flanges constantly grinding against the rails.

With a view to compensate on curved lines of rails for the different lengths of pathway on the two rails, it has been a practice to make the wheel peripheries conical instead of cylindrical; *i.e.*, each pair of wheels fixed on the axle being practically a garden roller, with the central portion removed, are made at each end a frustrum of a cone, with the smallest diameters outside. Were the rollers solid, *i.e.*, were the coned lines prolonged till they met in the centre, the roller, if balanced, might run in a straight line, or it might run in a curved line to right or left, if bearing on either cone, the curve being regulated by the angle of the cone. This would be the case with a single roller. But it is a fallacy to suppose that two or more rollers fixed in a frame, with their axles permanently parallel, would follow the same conditions, even though sufficient end-play were allowed between the flanges and the rails to make the differing diameters across the breadth of the tires available to compensate for the different lengths of the rails. The movement in a straight line might be free rolling at low speed, provided the cones had sufficient lateral movement or end-play, but on curves it would only be sliding or sledging. But if the frame were so arranged that the axles were permanently out of parallel by reason of careless workmanship, the machine would be a constant sledge both on straight and curved lines. So also, if the axles were perfectly parallel, with the wheels in the same plane, but were not placed at a right angle with the line of traction, the result would be constant sliding friction.

In any of these four conditions—whether a truly constructed frame, with parallel axles, or badly constructed with axles out of parallel, or badly constructed with parallel axles, and wheels out of plane or not at a right angle with the traction rod, though the first may roll at intervals under a favourable condition, the three latter must always slide, and the resistance to traction will be in proportion to the roughness of the rails and the load on them. With a light vehicle, little loaded, smooth wheels and polished tires and rails, and especially if they were lubricated on the surface, the resistance might be very small. Nay, a sledge might even be better than a wheeled vehicle, if only the condition of a lubricant could be retained. But a lubricant on the rail is inadmissible, first, because it would cause dirt to adhere to the rail, and secondly, it would defeat the condition of adhesion essential to the traction by the locomotive engine. The engine needs the greatest possible amount of adhesion, corresponding to the steam power. The vehicles should be so constructed as to minimize the amount of resistance. But as at present constructed, the vehicles on a railway are in principle a reproduction of the old Roman cars on two rollers, with such variations as a better or worse condition of workmanship or lubricant may induce, and the change from a common road to a railroad.

Axle friction, under the best conditions, is commonly estimated at about four pounds per ton of load, but this is usually doubled by a condition that under the best treatment ought scarcely to exist, viz., "rolling friction," *i.e.*, the friction of the tires on the rail, and thus at a moderate speed on the level, eight pounds per ton is estimated as train resistance. But this, it is well known, is very far short of the real resistance in practice, which by quick curves and bad structure may be quadrupled and quintupled, varying with the speed of movement.

A river running with a slow movement may pass along a winding channel without disturbing its banks; but the same river, with its speed increased by sudden influx of water, seeks to make a straight course, and cuts away its banks, or *rives* them, in a mode corresponding to its etymology. Even so, a railway train at high speed becomes a *river* of the rails, at an increased cost of coke converted into steam; and like the river water, it produces debris, not in the form of gravel, but of black iron powder, as anyone may verify by rubbing his finger along the rails after the passage of a train. This is frictional destruction, increased or diminished in proportion to the load on each wheel.

But there is yet another element of destruction—percussion or blows, which take place between wheel and rail, friction and percussion being the only sources of mechanical destruction on railways—the others being chemical. It is quite clear that were a train to stand still on a railway, and never move, it might rust and rot, but it would not wear out, and though the proverb is a sound one, "better rub than rust," it is still better to do neither. The movement of the train begins the great destruction, and it is want of compensation for irregularities—a condition never disregarded by nature—that causes the destruction. The wheels, when running on unequal paths, induce great torsion of the axles by friction on the rails. At bad joints or uneven surfaces the wheels jump from the rails, and they then recover their normal position, by the axle as it were unwinding itself, like a discharged spring, and striking a violent blow on the rail. Sometimes the wheels, with the axles in a state of torsion, drag along for a considerable distance, heavily loaded, and this is a fruitful source of axle breakage as well as of rail destruction. Again, the flanges strike against the rails from side to side, and a constant succession of blows and vibrations is induced throughout the whole of the train. And with long vehicles, on sharp curves, there is a constant tendency to grind the flanges and burst out the rails. The rapid wear of wheel tires and rails yields ample evidence of this, and the probability is that at high speed the movement is as much sliding as rolling—side as well as forward sliding. But for the partially polished surfaces of both wheels and tires facilitating slip, at the loss of adhesion on the driving wheels, it is probable that the destruction would be much more rapid.

Are there proofs needed of all this? Time was that rails of 60 lb. per yard, and Staffordshire tires too tough in texture to break, were capable of considerable duration. They have gone by, and rails, after various experiments in making them harder in iron, have grown to 84 and 90 lb. per yard, and with Bessemer steel for metal; and tires, after running through the phases of Park-gate, Low Moor, and Leeds, and various plans for steeling their surfaces, have now culminated in Krupp's solid steel.

It is many years since the writer became aware of the importance of elastic action, even on wood wheels used on highways and paved streets, to induce durability, and facilitate traction when high speeds were needed. In the structure of the ordinary wood wheel the strength resides in the tire, which keeps the weak frame together. Originally wheels were made vertical, *i.e.*, with the spokes all in a plane, and the width of base was determined by the ruts or hollows which pervaded all roads, giving a kind of fixed gauge, much as rails do now. The bodies were placed between the upper part of the wheels; and when it was needed to widen the bodies, the wheels were made in the form of a cone, or what is called "dished," the axle arms being pitched downwards to keep the lower spokes vertical, with an idea of strength, while the upper spokes inclined outwards, with a considerable angle. The fellies and tire were made conical, to preserve a flat tread on the ground. It is evident that as these wheels revolved, they were constantly grinding the road, the outer side of broad wheels being considerably less in diameter than the inner, while the vertical spokes were continually driving into the nave and loosening the framing.

After trying some experiments with wheels in which hoops of elastic steel were used to connect the periphery with the nave, instead of spokes, the writer had some made with the section of the wood spokes reversed. The ordinary mode is to make the spokes deepest from back to front, but in the improved samples they were made broad in the plane of the wheel, and thin from back to front. As this was a bad form to fasten in the ordinary nave, it was dispensed with, and a pair of disc plates was substituted, between which the spokes were mitred together and bolted. One felly was used to each spoke, instead of the ordinary practice of one felly to two spokes, and when cylindrical tires—not conical—were shrunk on, the spokes curved from back to front, and the wheel, instead of being a rigid cone, or dish, became an elastic dome, each pair of opposite spokes radiating from the centre, representing the form of an archer's bow. The fastening of the tires was through the joints of the fellies. When applied to a straight axle, with the arms not pitched downwards, the load was carried, not on a rigid vertical, but on a bent inclined spoke, and the result was that the load was not only carried more easily, but the wheels were, for their scantling, the most durable ever constructed.

Fig. 1.

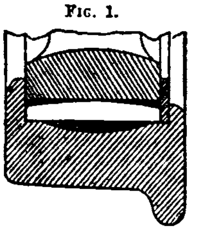


Fig. 2.

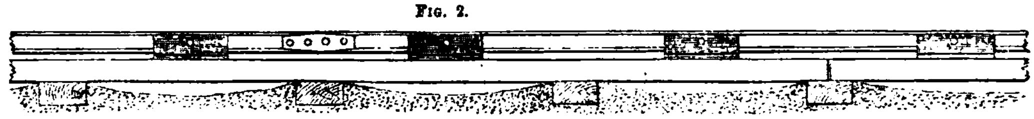
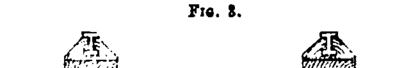


Fig. 3.



In the early railway wheels the principle obtained of neglecting the structure of the frame, and making it depend for strength on the shrinking of the tire, just as wood wheels were made. One result of this was the flattening of the tire between the spokes, and a tire of unequal thickness when turned in the lathe to make the external periphery a true circle, and a consequent rapid destruction in wear. This applied to the wheels with the wrought-iron spokes. The truest formed wheels were those of cast-iron with a wrought tire. They might break if of careless moulding, but they would not otherwise alter their form, and the tires could be all of equal thickness, but upon rigid cast-iron wheels the tires became exposed to very rapid destruction as the loads increased.

The writer had early turned his attention to the importance of wood wheels for railways, and as far back as the year 1838 caused some to be constructed with two rows of fellies, breaking joint between the tire, and a cast centre. They worked well, and the writer has been informed that they still exist. The difference between these wheels and the modern wood wheels is, that they had the elastic side grain on the tread, whereas the modern wheels have end grain. The reason for substituting the latter less perfect method probably was the difficulty of insuring dry timber on a large scale, and wood shrinks scarcely at all endwise, so that the shrinkage involves less evil.

Wood wheels on railways are, as now made, solid discs, and therefore the frame preserves its circular form without being excessively rigid. Iron wheels have also been made in the disc form, both in cast and wrought iron; but then, extreme rigidity rendered the destruction of the tires a very rapid process; the tire was between two anvils—the frame of the wheel, and the rail supported on chairs of cast-iron.

To prevent this destruction, the writer early devised a wheel in which the spokes were all springs, but that did not answer, because the bending of the spokes prevented the wheel from running true. The next plan was to apply a hoop of elastic steel between the tire and the periphery of the wheel, with a hollow below the steel. The wheel was retained in the tire by a rising rib in front, solid with the tire, and by a lower rib behind, sprung into a groove of the tire. (Fig. 1.)

The plan was satisfactory in theory, but how to put it in practice was another matter. A railway was needed, and railways are not to be found in a private field or park; they are the highroads of the public, and in charge of officers whose first care is to take no risk by an unknown plan; for if an accident happens through a known plan in common use, however faulty in its mechanical philosophy, a jury will acquit the manager of all blame. But if the accident happens with a novel plan, however theoretically right it may be, the jury will probably condemn it as new-fangled, and saddle the manager or engineer with the blame; and thus there is a natural indisposition in engineers to step beyond their tether into the unknown, and they can hardly be blamed for their caution.

So the writer went forth on his propaganda to expound an unknown quantity, but few would even listen to him, and none would believe; but strong in faith, he persevered, and at length found an engineer with a logical mind, in the locomotive superintendent of the North London Railway, Mr. William Adams. The writer demonstrated his principle, and Mr. Adams was unable to disprove it logically, whereon the writer remarked, "If you cannot demonstrate it to be wrong, and I demonstrate it to be right, and that the result if successful must be very advantageous, you are bound to try it." He agreed to this, and said, "I will try it, though doubting greatly. What wheels will you apply it to?" "Those most destructive to tires."

So a set of wrought-iron disc wheels were selected, and Staffordshire tires were applied to them on hoop springs, and they were placed under a heavy carriage. At the same time a set of ordinary spoke wheels, with a set of Low Moor tires fixed in the rigid mode, were applied to a similar carriage. The Low Moor tires required turning up to restore their surface after running less than 50,000 miles. The Staffordshire tires on springs ran 106,000 miles without turning up, and with no alteration of form, and were then taken off to exhibit, and may still be seen in the same condition.

There is no mystery in this. The Low Moor tires were exposed to severe wear. First, because on curved lines they were necessarily forced to slide on the rails, both forward and laterally. Secondly, because they were rigidly fixed, and possessed no elastic yielding to elude blows. Thirdly, because on curved lines there was a constant torsion of the axles, causing incessant jumping. Fourthly, because the tires had no power of lateral movement to suit the varying inequalities of the rails. In short, there was no compensation for irregular movement, and the result was a constant grinding of the flanges and treads.

With the spring tires, on the contrary, there is universal compensation. First, there is no tendency to blows, because the elastic cushion preserves constant contact between tire and rail. Secondly, there is no torsion of the axle or slipping of the tires on the rail, because the wheel can, on curved lines, slip in the tire on the smooth surface of the spring without damage, thus equalising the pathway. Thirdly, the tire can rock laterally on the wheel to adjust itself to the bearing on the rail surface, which any one may observe to be constantly varying, sometimes the middle of the rail being most prominent, sometimes the inside edge, and sometimes the outside. No other class of wheel can supply these various compensations.

Important as these wheels are for vehicles which are simply drawn, in order to remove resistance, they are still more important for engines with the load greatly increased, and especially for driving wheels—more especially for engines with four coupled drivers. It is obvious that if two wheels of equal diameters be fixed on the same crank shaft, they must grind and drag on curved lines, and the torsion thence ensuing is the main cause of the breakage of crank axles, which it is difficult to make strong enough for their work, the axle being in reality a very long axle, as would be readily apparent were it stretched to a straight line—between eight and nine feet long on the narrow gauge. When four wheels are coupled, the diameters very rapidly alter by irregular movement, and the adhesion may actually become disadvantageous, retarding the engine by friction, like a brake. It is clear, therefore, that the power of slipping the wheel within the tire to compensate for curves and irregularities becomes a question of the greatest importance, both as to facilitating haulage and preventing the wear of tires.

It has been at times assumed that the slip of the tire on a wheel must defeat the purpose of haulage. But when it is remembered that the bearing of the wheel is over half the diameter by downward pressure, and that with a heavily-loaded wheel a slight flattening of the tire takes place, it is obvious enough that slip will only take place by excessive friction on the rail; this is the true theory, but, for the satisfaction of those who only believe in practical results, it may be stated that the experiment has been tried repeatedly, and it has been found that when the tires were so loose on the springs as to be turned round by hand with the wheel lifted, the haulage was in no way affected. On a London line, of sharp curves, where the leading tires of ordinary engines with parallel axles had their flanges constantly ground off in two months' wear, a bogy-engine was set to work with a turning centre to radiate the leading axle to the curves. At the same time a similar-sized engine, but with parallel axles, was applied with spring tires to the leading wheels. The result was that in both cases the leading flanges were saved from damage, and ran three times the ordinary distance. The yield of the springs had an effect similar to that of the play of the axle to right and left in the bogy, when truly centred, for if not truly centred the flanges wore unequally.

These spring tires were adopted on the engines of the St. Helen's line, by Mr. James Cross, the engineer. That line is an incessant continuation of sharp curves and gradients, some of the latter 1 in 35, and some of the former two chains radius. The spring tires were first applied to a six-wheeled engine, all coupled drivers of 4 feet diameter. They were all of Staffordshire iron. At the same time another engine of less weight, also on six wheels, but of 4 ft. 6 in. in diameter, and only four coupled, was fitted with tires of Krupp's steel. After running 41,000 miles, Krupp's tires were so deeply worn, as to need turning up, while the Staffordshire iron tires ran 65,000 miles, and then only required the flanges to be reduced which had been deeper at the outset, the tread of the tire remaining in good shape. Taking into consideration the difference of diameter, the distance run by the Staffordshire iron was as 72,000, against Krupp's steel 41,000. In practice, Krupp's tires were found to slip on the rails even in dry weather, but the Staffordshire iron was scarcely ever known to slip, though working steeper gradients and sharper curves.

Another set of experiments was tried with two fellow engines, one of them fitted with spring tires, the other with rigid tires, up a gradient of 1 in 80, during a whole day, by the same driver. The result was, that the rigid tires constantly drew up thirteen loaded coal waggons, and the spring tires fifteen.

The result of this elastic principle having been so unmisteakably advantageous in wheels, the writer began to consider whether the same principle might not be practically applicable to rails also. It is clear that the destruction of rails arises from blows between the wheel tires and the rails, increased in destructive effect in proportion to the load, and therefore it is that it is now proposed by some railway companies to substitute steel for iron in rails as well as tires.

On the North London Railway the rails are 82 lb. per yard, and their average duration on the main line does not exceed four years, if so much, the traffic on each pair of rails being upwards of 120 trains per diem of goods, coal, and passengers. The great wear is not owing to wear of attrition, but to crushing, disintegration of the laminæ. The rails are double-headed, and worn out on both tables before they are taken out. The sleepers are 3 feet apart, and the rails are fixed in cast-iron chairs with wooden keys, the joints being fished with long fishes and four bolts.

Iron rails are in their manufacture practically "scrap iron." They are formed of bars of various sections piled together and heated, and then rolled out. In the act of heating, the oxygen of the atmosphere gets access to their inner surfaces, and scale is formed. This scale does not roll out, but rolls in, keeping up a constant separation of fibres like the grain of wood. With a certain intensity of blow on the line, the chairs and sleepers serving as anvils, the fibres are crushed apart, and the utility of the rails is destroyed.

Steel rails are not formed of separate masses welded together, but each of a single ingot rolled out without flaw or imperfect junction. They are homogeneous, which the iron is not, and therefore do not disintegrate with the same amount of blow which disintegrates the iron. But to be safe, the steel rail requires to be not only homogeneous in metal, but in the temper of the metal also. If a steel rail be taken hot out of the rolls and thrown on a cold iron or stone floor, it may become partially chilled—hard and soft—and in this condition it is apt to break, for which reason it is always recommended to keep the steel rails as soft as possible, to prevent risk, in fact to reduce them to the condition of iron. But the better plan would be to use spring steel, and harden and temper it.

There is a notion prevailing that permanent way on cross sleepers is elastic by virtue of its discontinuous bearing. But it is obvious that if there be any yield of the rails between the supports, there is none at the chairs themselves. If the rail be loose in the chair, which it commonly is, and if the sleepers be loose in the concreted ballast, which they are commonly, the looseness only serves to give momentum to the blows of the wheels, so that the rail drives into the chair, the chair drives into the sleeper, and the sleeper drives into the ballast, while the fish joint bends at the weakest point.

On a portion of the main line of the North London, the rails and chairs being taken up, longitudinal timbers, 4 inches deep by 11 inches wide, were spiked down to the sleepers. On these longitudinals, midway between the sleepers, were placed cast-iron brackets in which the rails were fixed, suspended by the upper table, and not resting on the lower table, as in chairs, the bottoms of the rails being 1½-inch above the longitudinal timber, so as not to touch it. The joints were fastened as usual. The cross sleepers were packed hard and tight on solid ballast. The longitudinal timbers were not packed, the result being that the rails were continuously supported on an elastic base. With the traffic of the trains the mechanical action was, that no wheel pressed directly on a single sleeper with a hard blow, but that the weight on each wheel was distributed over two or more sleepers, and that through an elastic medium. Practically, after nearly three years' wear, none of these rails have been found to disintegrate, but are as perfect as when first laid down, except where connected rigidly to the ordinary line, and there the ends of the rails are split; and the elastic action is not merely vertical, but horizontal also, by a slight twist of the longitudinal timbers preventing side blows from the flanges of the wheels.

It was also found that the sleepers remained quite undisturbed in the ballast, owing to the distribution of the weight, and that they really became sleepers, instead of dancing up and down. Moreover, the provision for elastic action dispensed with the practice occasionally resorted to, of digging up the ballast below the sleepers to soften it, and prevent the extreme rigidity. It is getting to be a known fact that constant traffic and the use of heavier engines and vehicles is gradually solidifying the whole of the railway lines, so that the destruction of the plant, both fixed and rolling, is on the increase. A superintendent of a long line running on hard ground informed the writer that he contemplated re-spacing the whole of his sleepers in order to use the softer intervals. An illustration of this great evil may be found in the fact that in the winter time, when all the ground becomes hard with frost, the destruction of wheel tires and rails by breakage is greatly on the increase.

After the successful result of the first experiment on elastic lines, the superintendent of permanent way, Mr. Matthews, laid down a second portion, in which the cross-sleepers are 6 feet apart, or double the ordinary distance, the supports of the rails on the longitudinals being 3 feet apart. The same result was obtained in preserving the sleepers steady in the ballast, though the elastic yielding was greatly increased, being quite perceptible under the rolling trains.

Ballast in England and elsewhere has become a kind of stereotyped custom on railways, though there are districts, as Egypt,—the Southern States of America—(where a driver "guesses he never runs on ballast, but only on mud roads")—the Pampas of Buenos Ayres, the Llanos of Venezuela, and elsewhere, where no ballast can be had, and so it is dispensed with. But the theory of ballast has hardly been considered. It was originally used on non-porous soils, as a kind of easy drainage for surface water, and in some places tolerably cheap. And it does not yield like clay. But it very soon ceases to be porous under the sleeper, and becomes a kind of conglomerate, or concrete, each sleeper pit holding water like a pond. But, inasmuch as it has been practically demonstrated that with a provision for elasticity the sleepers may advantageously be rigid fixtures, there seems to be no reason why the whole surface of a railway should be covered with eighteen inches

It is desirable that the rails should be of such depth as not to deflect beneath the wheels, and also that they should not deflect laterally, for which reason the tables should be of ample width. It is also important that the rails should be so joined together as to form non-deflecting bars at the joints, though with provision for expansion and contraction. In examining the ordinary fishes it will be perceived that the original principles of the writer's invention have not been carried into effect. These fishes, as ordinarily used, are parallel bars, about eighteen inches in length, and with four bolts to attach them to the rails. As the total depth of the fish is only between two-and-a-half to three inches, it is obvious that a pair of three-inch bars cannot possibly be equivalent in strength to a rail five inches in depth, and provided with two broad tables. In order to compensate for this defect in some measure, the fishes are made as thick as possible, approaching an inch, making them very rigid. They are wedge-formed between the rail-tables, but at an obtuse angle, not an angle of repose, and they depend wholly on the bolts to keep them in position under the action of the trains, and the slightest movement of the rail loosens them. For this reason the bolts are made as large as possible. The large hole weakens the fishes, and it is necessary to drill the holes, as punching distorts a narrow thick bar. Moreover, as the fish is as thick at the ends as

Fig. 4.

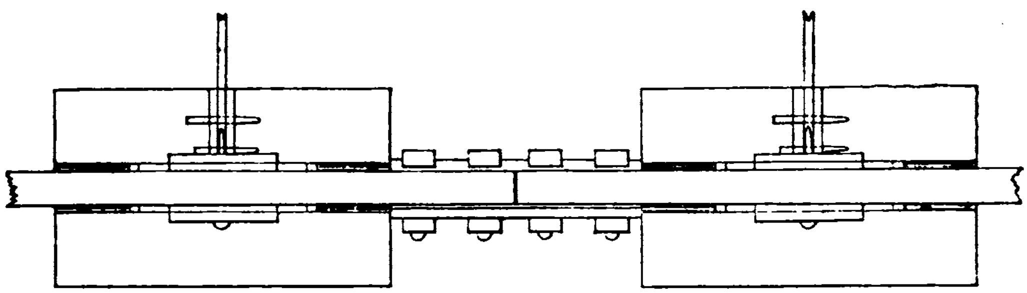


Fig. 5.

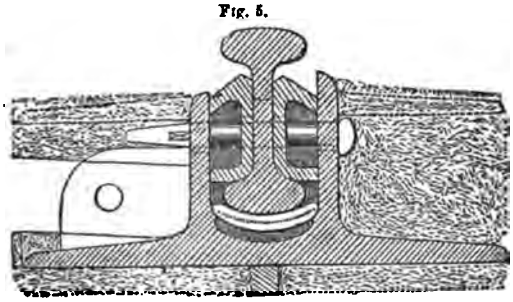


Fig. 6.

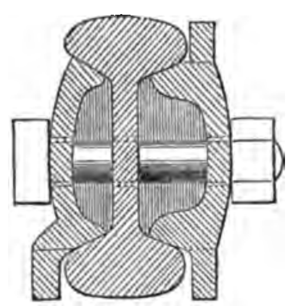
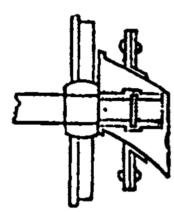


Fig. 7.



of gravel or broken stone, varying in price from 1*s.* to 2*s.* 6*d.* per cubic yard. The object should be rather to cover it with non-porous material, so as to keep out the surface water, the same principle on which we pave the footways of our streets; and there is no doubt that it would be cheaper, in many cases, to use stone flags or cast-iron for sleepers, rigidly fixed and overlaid with elastic longitudinals, so as to dispense with ballast, even in first cost, saying nothing of the saving in maintenance. As regards such lines as are constructed on brick arches, the elastic system would prevent the vibration which so commonly disintegrates them, and, by ramming down the ballast, forces out the parapets; and it would be better to cover the surface with non-porous material, such as paving-stones, and get rid of mud and dust altogether. The action of this novel system depends upon the elasticity of the longitudinal timber; but inasmuch as there are circumstances in which timber is inadmissible, such as very hot climates, or climates of great heat and moisture combined, or alternating, the writer was led to consider whether it might not be practicable to obtain the elasticity by the agency of metal. This can be done in two methods, substituting a broad T iron for the longitudinal timber, or by applying springs of tempered steel beneath the seats of the rails, which in that case cannot be suspended by the upper table, but must rest below the vertical web, being supported between the bracket sides, with provision for the small amount of movement required. Two models of cast sleepers are on the table, with elastic steel bases. The cost of them will not exceed ordinary iron way, as great weight of metal is saved.

at the centre, the result is a blow from the wheel at the fish end, where it is too strong, and a second blow at the joint where it is too weak, and a gradual dent of the fish end into the rail, and another dent of the rail-end into the fish; and when these dents begin to form, the process of destruction is certain; rust is formed, rubbed off, and begins again; and the noise and jolt is rendered very perceptible to the passengers before the cause is detected by the eye, except when a train is passing, when the deflection is very perceptible.

To remedy this, the writer has devised a true form of fish. It is tapered from the ends towards the middle, where it is the full depth of the rail on the outside fish, and on the inner the full depth of the rail, less the upper table, to make room for the wheel flanges. Angular ribs are rolled on the inside of the fishes, to fit accurately against the rail tables, and the fishes are arched laterally. The metal being thin, except at the ribs, they are easily punched without distortion, and when the bolts are screwed tight, the arches of the fishes flatten and press the ribs against the rail tables firmly. The bolts thus acting on elastic surfaces, the nuts remain tight, and the joint is elastically firm. The models of the elastic way, both in timber and iron, with steel springs, as well as the improved fish-joint. (Figs. 5, 6, 7.)

The writer has dwelt upon this subject the more earnestly, because on any new plan connected with a railway a protracted experiment is needed for verification, and this protracted experiment of elastic railway has been made, and can be examined by all who feel an interest in so important a subject.

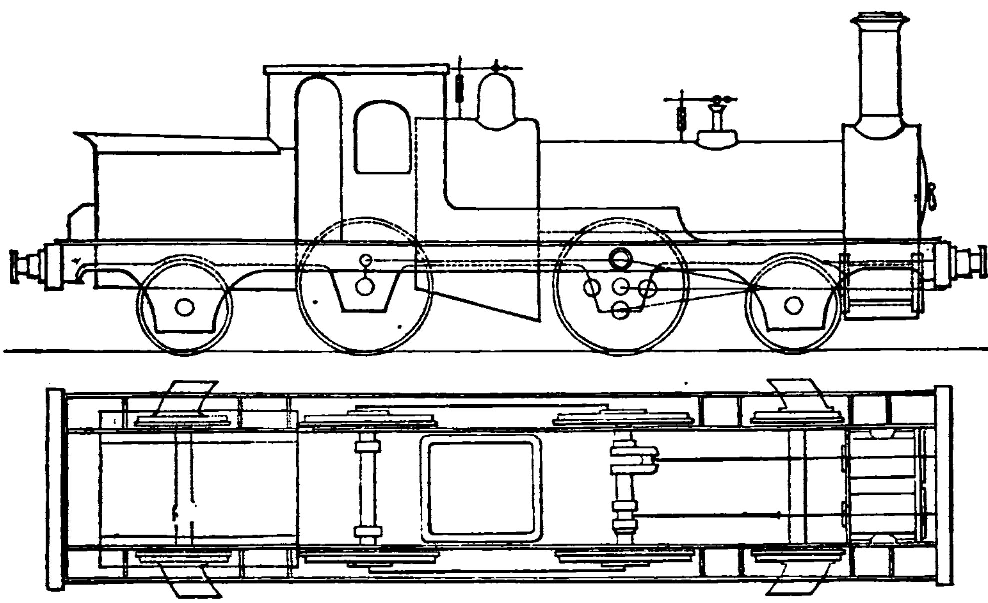
Having obtained successful results in the elastic action both of wheels and rails, the next question was to obtain a true mechanical action in the movement of wheels and axles. As far back as the year 1837, the writer had sought to impress upon railway authorities the importance of radial movement in the axles, enabling them to run at a right angle with the rails, whether on straight lines or curves, and proposed various modes of accomplishing it, but he could get no attention. The railways were made in what were called straight lines, through practically crooked lines, and it was taken for granted that the coning of the wheel tires accomplished all that was wished. But in America, crooked lines obtained with very sharp curves, in order to go round street corners instead of outside the towns, and a bell was suspended at the entrance, to be struck by the engine, and a notice painted on a maple slab, "Look out for the locomotive when the bell rings." To facilitate the movement of the engine round the curves, the front end was provided with a swivelling truck, called a bogy, analogous to the ordinary under-carriage of a road vehicle, moving on a centre pin, but with four wheels instead of two, the wheels being guided by their flanges against the rails, instead of by a pole. This was so convenient, that it came into general use in America, and it was first introduced into England on the Birmingham and Gloucester line, the engines being made in America. But it was defective in principle. In ordinary under-carriages on the road, the length of the pole steadies the wheels. In the four-wheel bogy, the distance between the front and back wheels was less than the width between the rails, and consequently, swivelling on the centre pin, the bogy was apt to run unsteadily, and drag the wheel flanges against the rails, the contact with the outer rail on curves setting the axles askew to the rails. This evil was continued on the South Devon line, where, the sharp curves necessitating the use of the bogy, it was applied on a 7-feet gauge with the wheel centres 5 feet apart. In addition to this defect, apparently resorted to to compensate in some measure for the fixed parallelism of the axles, it did not in any way help the askew position of the driving-wheels, as the central pivot did not permit lateral movement of the bogy. To remedy this, Mr. Bissell, in America, devised a plan of removing the centre pivot from midway between the four wheels to a point between the driver and the bogy; thus the movement of the wheels became radial, or in the circumference of a circle instead of the centre. This was a plan on which the writer had built road carriages long previously, under the name of Equirotal carriages, and had proposed to apply the principle to engines. Mr. Bissell subsequently applied the same principle to engines with two-wheeled bogies, and time and circumstances having forced on the attention of English engineers the necessity for radial movement, other attempts were made to correct the defects of the bogy, and one was by providing a lateral slide as well as pivot movement to the centre. But on this plan the guidance was lost, and it was not found to answer.

Seeing that the time was approaching for more perfect machinery and for radiating axles, the writer again set to work to simplify the structure. Abandoning the truck form, or bogy, altogether, the axle-boxes were adapted to slide in curved lines laterally through the horn-plates of a rigid engine frame beneath the spring bearings. The advantages gained by this were, first, true radiation of the axle to every curve, from the straight line, down to one chain and a half radius; secondly, perfect guidance and prevention of irregular movement in the wheels; thirdly, facility in axle-bearings and lubrications; fourthly, the use of larger wheels than could be obtained by the bogy system. (Fig. 7.)

The writer proposed to build the engine with coupled driving-wheels in the centre, and with radial wheels at the ends, eight wheels in all, and so, having ample support, to dispense with a separate tender. This was so novel a plan, departing from the customary bogy system, that it was not listened to, and bogies were continued.

The writer sent a drawing to Mr. Cross, the engineer of the St. Helen's, and about nine months after received a letter from that gentleman stating, that having found it necessary to use larger engines for his increasing traffic, he had studied the whole question carefully as to the best principle of radiation for his sharp curves; and having come to the conclusion that the plan of the writer was the simplest, safest, and most effective, as well as the least costly, he had constructed a model and verified it experimentally, after which he put in hand a full-sized engine. (Fig. 8.)

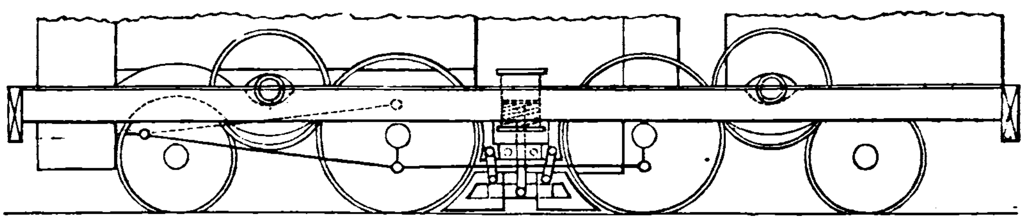
Fig. 8.



After working for some time on the St. Helen's, both for passengers, goods, and coal, and perfectly establishing the soundness of the principle, this engine, called the White Raven, was brought to London for experiment, and examined and experimented on by a large number of railway engineers, whose judgment confirmed the truth of the principle of structure. It was at first supposed that the free movement of the wheels would tend to make the engine unsteady on straight lines at high speeds, inasmuch as front wheels, fixed laterally in the horn plates, were supposed to exercise a steadying and governing power. But the contrary proved to be the fact. Another engine, altered from the rigid system to the radial, was found to run much steadier after the alteration, after acquiring the facility for rounding sharp curves. In truth, the unsteadiness of all engines, apart from bad construction, arises from the fact that the wheels, fixed to the frame, and seeking the path of least friction over uneven rails, force the frames to partake of their irregular movement; and as might be expected, the inertia of the engine frame keeps it steady enough when the wheels are left free to pursue their own courses unshackled.

This novel arrangement comes at a convenient time, as the extension of railways through towns and mountainous countries is now the prevalent thought. But, even for what are called straight lines, their extension into and through towns, and new station accommodation, renders it very important to have engines working round very sharp curves, and either end foremost. The great cost of land and the removal of buildings in approaches where only straight lines or very large curves can be used adds very materially to the cost of construction. But there is another question, quite as important. It is well known that the rapid wear of the rails of railways is very largely owing to the weight of the engines, apart from the train, and in the engines the destruction by rail crushing is increased in proportion to the weight on the driving wheels. Some engines have only one pair of driving wheels, as they involve less impedimental friction at high speeds. Some have two pairs coupled together, and some three pairs. Inasmuch as the engine draws the load by reason of its own weight on the rails giving adhesion, it follows, of course, that a heavy train needs more weight on the driving wheels than a light one. When a single pair of drivers are used the load sometimes approaches to fourteen or fifteen tons, and this crushes both rails and tires. If, however, the load can be distributed over more wheels, this destruction may be avoided. Twenty tons on four wheels is much less damaging than fourteen tons on two wheels. For this reason our continental neighbours have been aiming at two things combined—to obtain the adhesion of many wheels, with the facility of passing round sharp curves. The ordinary method of coupling wheels by side rods does not admit of this, and the writer has resorted to another method, illustrated by the model on the table, which, as regards its eight lower wheels, is precisely similar to the St. Helen's engine, the White Raven. But in addition to this it has four other wheels, two of which are placed at each end, resting between the central driving wheel and the end radial wheel on their peripheries, pressing downwards with any amount of weight needed to induce adhesion. In fact, the whole weight of the engine and frame may be supported by the upper wheels, if needed. But practically a comparatively small weight is needed, as the wheels do not merely rest on one another, as is the case with wheels on rails, but have also a wedging action, which may, if permitted, produce an intense pressure. All the wheels have also spring tires, which ensures elastic contact and fit, without blows. It will be seen that when the driving wheels are put in motion, they communicate that motion by friction to the upper wheels, which in turn communicate the motion to the radial wheels, and continue to do so when the radial wheels are on curves, the effect being that the axles of the upper wheels depart from the horizontal line, dipping to right or left according to the lengthening or shortening of the distance between the lower wheels on curves. And the adhesion is perfect, because the load on the upper wheels forces down the lower wheels to a perfect pressure on the rails at either end of the engine. Thus there are eight drivers, which may be equally loaded, and the whole weight of the engine is available for adhesion. And in reversing, for the purpose of retardation, the whole of the wheels are available. To make the machine complete, brakes are applied between the driving wheels, arranged to act both against the wheels and rails by small steam-cylinders, so that the retardation of the engine is within the control of the driver by simply turning his regulator and steam cocks, without needing the muscular force of his fireman, labouring at a screw with slow movement. It will be seen that this engine will run on S curves as easily as on regular curves. (See Fig. 9.)

FIG. 9.



Of course the steam power of an engine should be in proportion to the adhesion. Practically it is far in excess of the adhesion, inasmuch as sand is commonly used to prevent the slip of the wheels; and this, though useful to the engine, is a serious disadvantage in increasing the resistance of the train. This seems certainly the case on the Great Northern, where it is found advantageous to make the tender wheels drivers, as well as those of the engine, with the same boiler power.

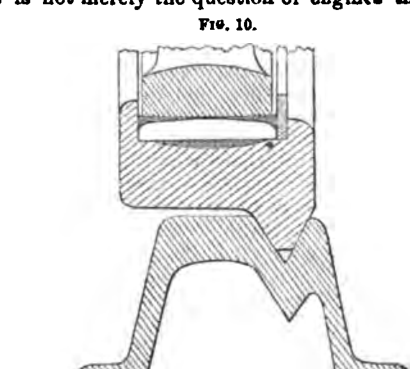
In the early days of railways the difficulty of adhesion between a smooth tire and smooth rails was considered to be great, before it was tried. But in those days the trains were light, and the increase in weight has again drawn attention to the desirability of increasing the adhesion. Racks on the rails and wheels might no doubt be used, as they have been, and as they still are in some collieries; but this can only be for very slow movement. Yet there is a mode of increasing adhesion not yet resorted to, but which will probably be resorted to, where the whole difficulty of mounting steep ascents, such as one in twelve, or 440 feet to the mile, shall occur on any sharp curves. It is to convert the rounded flanges of the wheel tires into two flats at an angle of 45 degrees, and enlarging them to take a corresponding groove formed in the surface of the rail. The driving wheels of the engine only are to be fitted to these grooves, and the ordinary flanges of the train wheels can easily pass, being of smaller size. It may be remarked, that it would not be easy to lay rails accurately enough for this, and especially on curves, but compensation can be easily provided by the use of spring tires sliding laterally on the wheels, and there is no reason why the eight coupled engine before described should not work perfectly well in this mode, on sharp curves and stiff gradients. (Fig. 10 illustrates this.)

Thus with radial axle, spring tires, angle flanges, and elastic permanent way, several difficulties are got over. The blow and sledge movement is removed from between wheel and rail, as well as the grinding action against the flanges, and the adhesion is ensured, while the permanent way is rendered really permanent.

It may be objected to that the angular flanges will tend to wear away both tires and rails. This is quite true; but if we want to do hard work we must pay for it in some shape or other. The only question is, is it worth doing; and if so, what is the least costly method as well as the most effective and simple? We know that we can drive machinery by friction pulleys, and there is no mechanical reason why we should not drive railway trains. And these tires can be removed and replaced with perfect facility without needing workshops.

But it is not merely the question of engines that we have to deal with. It is that of carriages and waggons also. These vehicles have been kept short, and their wheels disadvantageously near together, chiefly on account of the difficulty of curves. This system needs remodelling; but there are so many considerations that it must be deferred to another paper.

FIG. 10.



(To be continued.)

OFFICE BUILDINGS IN THE CITY OF LONDON.

By E. I'Anson.*

City Offices are certainly a new and striking feature in some parts of the city, and so important have they become in extent, and involving such large financial operations, that during the last twelve months two or three companies, at least, have been formed for the erection of new offices, or for the purchase and management of offices already formed, one of which, it states, had agreed to purchase property to the extent of £365,000, and whose proposed capital was one million sterling; and when, as I have heard it stated in evidence, that one gentleman alone, who is interested in property of this description, is in receipt of an income of £36,000 a year from offices in which he is interested, and which, indeed, I believe he himself has constructed; when such sums as £50,000 to £60,000 are commonly given for the acquisition of sites, and like sums spent on the erection of single blocks of buildings, you will appreciate the magnitude of the interests concerned, and the importance of some of the buildings which are now erected to subserve the requirements of commerce; and although none of the buildings which I am able to illustrate by the drawings before you are of this magnitude, still in character they are all much the same.

I will now refer to a few examples of the Office Building class. One is a building known as Langbourne Chambers, Fenchurch-street, very recently erected; the architect is Mr. James Sheppard Scott. It has simply an entrance from the street, so that externally it has no architectural feature. It had also extremely limited opportunities of obtaining light through its boundary walls; wherever this opportunity did exist, it has been taken advantage of to the utmost extent, but the chief light is obtained by the internal areas formed within the block of the building, these areas being all lined with white tiles; and on the ground floor there is an ingenious contrivance for obtaining an extension of skylight by splaying back the walls of the areas above the skylight level.

There is another plan of offices built next adjoining to one of the ancient churches in the City, St. Helen's, Bishopsgate-street, a stack of offices built by Mr. C. J. Corbett, an architect I have before referred to, who has built largely, and principally on his own account. I may here mention, incidentally, some somewhat curious points of practice which arose out of the building of this stack of offices, and in which, as being professionally concerned for the freeholder, I became a party. One was, that when the old buildings adjoining the church were removed, it was found that a window belonging to the church had been bricked-up since the Reformation, and the parish demanded as a right that, notwithstanding the length of time during which the window had been closed, that the church should re-obtain its ancient light, asserting that no time was a bar to the rights of the church. Another point which arose was, whether the owner of the adjoining house, which had been pulled down, and which, since the Reformation, had used the church wall as a party wall, had a right in respect of this wall to use it as an ordinary party wall, and to deal with it under an ordinary party wall notice under the Building Act; and Chancery proceedings were actually begun to determine the rights of the respective owners, but they were subsequently compromised, each party making concessions, so that the rights of the contending parties were never legally determined; but by one concession made, the church regained its ancient window after it had been closed some three hundred years.

Another set of chambers, are the Colonial Chambers, Fenchurch-street. This building is almost wholly lit by internal areas, and except towards the street has no external windows at all. The cost of this building came to very nearly 10*d.* per foot cube. The areas are all lined with white tiles, and the front next the street is a stone front. The entrance door next the street is an open iron door, a feature which I have introduced in most of my office buildings, as I think it serves by night and by day to admit air and ventilation to the halls, passages and staircases.

Bell-court, Mincing-lane, unlike the last building, is wholly lit from its external walls, and the lights, where not obtained over areas already existing, were obtained by arrangement with adjoining owners. The cost of this building comes out at about 8½*d.* per foot cube. It has a narrow frontage on the street of stone, and, like that last described, this also has a stone front, but this is exclusive of ironwork and some other matters. A structure built for the Colonial Life Assurance Office, Lombard-street, has recently changed hands, and is now used for a bank. I may mention that this building, or rather the site on which it stands, has been quoted as an instance of the great value of property in certain localities. The area it covers is but little over 1000 feet, and the ground it was stated was sold at the sum of £30,000 but this is an exceptional instance, quoted to prove an argument, and can hardly be taken as a criterion of value. The adjoining building in Lombard-street has also the upper part used as offices, but the area of the ground was here so limited that it hardly afforded an opportunity for any special adaptation as an office building.

The offices over the Subscription Room at the back of the old Corn Exchange, Seething-lane, was wholly determined by the arrangement of the floor below, the room or offices above being subsidiary, the main object of the building having been the subscription room on the ground floor. The last four examples are of my own building, but the first two described of these more particularly illustrate the special subject of office building.

In planning this class of buildings, the distribution which it is most desirable to accomplish, is one which admits of a separate access to each room. The rooms are seldom formed of large size, seldom more than 20 by 15 feet, and often considerably smaller, and even when the rooms are constructed of larger sizes, they are generally so arranged with fire-places, entrances, and windows, as to be capable of being divided into smaller rooms; the position of the fire-place is not important, for it is not used for sitting round, but simply for warming the room; it is very generally placed, when the plan admits, at the back of the room, away from the window, and at all events, it is so placed that between it and the window there shall be abundant working room for a desk, the great object being to utilise, as much as possible, the space opposite the window. One of the most important points is to consider what is the minimum amount of space which it may be necessary to sacrifice for obtaining light and air to the various rooms. I recollect one instance where there is an area or shaft of three or four stories in height, lighting offices on both sides, not exceeding 7 feet in width, but I have myself sought to obtain a width of 10 or 12 feet; and as these areas are now invariably lined with glazed white tile, I have found this width to be fully sufficient, even for lighting rooms in the basement stories, which I have done successfully at the Colonial Chambers, Fenchurch-street; and in this case to obtain a light reflected upwards, I have splayed the lower part of the sides outwards.

A large amount of window space being of the first importance, it is desirable to economise, as much as possible, the bulk of the window frames; this has, in some instances, led to the adoption of single sashes, occupying the whole opening, which allows a frame of less depth than when the sashes are double hung. These large sashes are hung to turn on centres, but the same disadvantage attaches to them as to casements, namely, that in opening they derange the desk or table which is placed against the window. With the view of reducing the size of the frames, I have always made a part of the sash only to hang, but as constant window-cleaning is an important feature in the management of these establishments, I have always worked projecting iron brackets into the area walls, at convenient distances, whereon planks may be placed for the purpose of repair or cleaning. In forming the window I have generally placed the head above the level of the floor above, and in some cases I have formed bulkheads in the floor above, at the height of a desk, and splayed the ceiling below up to the under side of the desk above, being desirous of obtaining light as much as possible from the upper part of the rooms.

I have already alluded to the use of white tiles for lining the walls of the areas; this gives a very great advantage, not only in reflecting light, but the appearance is also pleasing, and it is very easily cleansed; every shower, in fact, helps to do this. They were first used by me at the suggestion of Sir Francis Moon, at Royal Exchange Buildings; and this, so far as I know, is the first instance of their application on a scale of any magnitude in city buildings. It is obvious that they may be made hexagonal in form, or square, or diamond-shaped, and ornamental borders might be introduced, but this I have never seen done, as the great object is to obtain, to as great an extent as possible, the best reflection of pure light. I have carried out this principle not only in internal areas, but also in two instances in the narrow passages in the city; one of which is Pope's Head-alley, leading

* From a paper read before the Royal Institute of British Architects.

from Lombard-street to Cornhill, where, having the control of the houses on both sides of the way, I was enabled to obtain the lining of the opposite walls; and another instance is the back of the building in Finch-lane, built for the Middlesex Bank, which abuts on a narrow court, and being opposite to a house in which I was professionally interested, I obtained that the back of the bank should be covered with white glazed tiles.

The staircases and landings are almost always of stone, and fire-proof. At the Middlesex Bank just alluded to, the staircase is of terra-cotta; the finishing and decoration are very simple. The chimney-pieces are also generally very economical in character; and indeed I have sometimes thought, in some of the finest and most profitable buildings of this class, that the chimney-pieces have been treated with too rigid an economy. The outer door to the office are generally made in solid frames, as they are constantly being used, and the frames are generally carried up so as to form a fanlight over the door, in which there is a swing sash fixed to open on centres, for the purpose of admitting air into the rooms from the spacious landings and staircases with which they communicate, and the door itself is usually a glazed door, which admits of placing the name conspicuously on the door, and at the same time gives light to the passages. I need hardly say that a most extensive use of plate-glass is made, both in the windows and screens; and it is remarkable how little sound passes from one room to another when separated with screens glazed with plate-glass.

Another obvious necessity is a good supply of water-closets, wash-hand basins, and urinals. Sometimes it is necessary to devote special rooms for this purpose, grouping the closets together in the less valuable part of the house, as the basement and upper floors. In the Colonial Chambers, which contains fifty-two rooms, I have provided twenty water-closets, and in Bell-yard Chambers, containing sixty rooms, there are about twenty water-closets, besides urinals and wash-hand basins in both cases; and I need hardly say that the cisterns must be of large size. In Langbourne Chambers, the architect has contrived an arrangement of pipes passing at the back of the fire-places, so as to procure a supply of warm water for the use of the offices.

To conclude, I beg to refer to some points of practice incidental to this class of building. One of the greatest difficulties which arise in building, not only office buildings, but indeed all descriptions of buildings in the city, is the serious difficulty which arises out of questions of light and air. The question suggests itself out of the subject of this paper; it is one which merits the careful attention of this institute; and although I am not prepared to offer any suggestion which would meet or mitigate the difficulties constantly arising out of the existing state of the law, I cannot but think that some course of proceeding might be adopted which would be an advantageous substitute for the law as it now exists. The only practicable course open to any aggrieved party, as the law now stands, if any adjoining owner has erected a building to his prejudice, is to bring an action for the damage done. This is always an expensive and troublesome mode of proceeding, and in the great and rational sympathy which exists in favour of the owner of a new and probably much improved building, and the extreme difficulty of proving to a third party who was not cognisant of the state of things which existed before the claimaint's lights were affected, it is hardly possible to obtain anything more than a nominal damage for the injury sustained. This has led to the frequent occurrence of applying for an injunction to prevent buildings being erected; and such a mode of proceeding has the very great advantage that it obliges the aggressor to justify his proceedings before he proceeds to raise his building, and before his case is strengthened by the prestige it acquires by the erection of his new building. An injunction is, however, often obtained upon very slight grounds, and when the interests of the objecting party, although actually affected, are comparatively extremely small in comparison with the interests of the party accused as the aggressor. So that, as I have before suggested, it would be most desirable that some better means should exist for solving this social difficulty, for I think it must be admitted that there is often considerable hardship in the law as it stands; and it is clear that if it were in all cases carried out, the houses of London must remain for generations unaltered in height—a condition which would alike be detrimental to architectural effect, and a very serious drawback to the value of property, completely negativing the theory that a freehold extends from the centre of the earth even to the heavens.

The case which, on account of the thorough manner in which it was worked out, became a standard authority, was the case of the Merchant Taylors Company against Truscott, and a particular interest attaches to this case, from its having been the first in which it was decided that a custom which by long use had grown into the authority of law—namely, the custom which, until this case was tried, allowed all persons building on old foundations in the city of London to carry their buildings to any height they pleased, then no longer existed. This was a custom—never directly repealed by any Act of Parliament, but it was held in this cause, by reason of the Act of the 71st chapter of the 2nd and 3rd George IV., an act for shortening the time of prescription in certain cases, to have been abolished. The injunction to restrain the defendants was sought for before the Master of the Rolls, who held that there was a *primâ facie* case for restraining the defendants in the execution of their work. Nevertheless, an account was taken of the condition of the building at the time; and an action at common law, the Court of Chancery not being then capable of hearing evidence, was directed to be tried, to prove the fact whether there was damage done to the light and air of plaintiffs' building or not. This cause was accordingly tried at the Court of Queen's Bench at the Guildhall, when the fact of a damage was clearly established; whereupon it went back to the Master of the Rolls for a decree; but as there had been some deviation from the old line of building frontage, the building having been somewhat set back, the Master of the Rolls appointed an eminent surveyor to advise him as to the extent to which the defendant's building should be pulled down so as to restore to the plaintiffs the same light and air as they formerly had, and the decree was made in conformity with the surveyor's report. The plaintiffs therefore obtained all the satisfaction which the court could afford them, but it subsequently became a matter of compromise, and a compensation was accepted for the damage done. I believe that there are still erroneous notions prevailing on the subject—one is, that the intervention of a street or public way justifies the raising of a building to any extent; another is, that a building may be raised, provided the raising is not to a height beyond a line drawn at an angle of 45 degrees from the window opening or openings, the light of which is affected by the raising of an adjoining building; another is, that skylights or horizontal roof-lights are not subject to the same law as ordinary vertical windows. All these are purely fallacious, and however distant the obstruction, or however brought about, if an ancient light,—that is a light which has existed twenty years, is injuriously affected by reason of the works of an adjoining owner—there is a cause of action.

There is, however, a quite recent case, arising out of the rebuilding of the noble pile of office buildings on the site of the old East India House, when, on appeal to the Lord Chancellor, there was a judgment given, I believe, of a character more favourable to those engaged in erecting new buildings, to which I am only able to refer, without giving the actual details of the case.

Besides the difficulty arising out of the state of the law, with which all who build in London are probably but too familiar, we have difficulties arising out of the special act which regulates Metropolitan buildings, namely, the Building Act,—one which is pretty sure to require attention is that section of the act which prevents our forming openings in an external wall exceeding one-half the area of the wall; and when you look at such a façade as that of Colonial Chambers, it would at first sight appear that the act had been contravened, but if you reckon up all the space below ground, in which no openings occur, there is enough to justify the building as it stands, and in fact it seldom happens that this is the serious difficulty which it at first appears to be. Another restriction which creates a difficulty is the limitation of the contents to the number of cubic feet which the act allows. This I have felt it necessary to provide for in my own buildings, by dividing the building by brick walls and double iron doors, so as to form it in compartments not exceeding the required cubical capacity; but in one of the largest of the city office buildings erected in Mincing-lane, where the division was not thus carried out, the matter was brought before the late Mr. William Cubitt, who was then, as Lord Mayor, the sitting magistrate, and in consideration of the building being built with fire-proof floors the division by vertical walls so as to obtain the required area was not insisted on.

There is still another practical point, but of a totally different character, to which I beg to refer you; for one element of success in these office buildings is a good organisation of such services as the offices require, which, although limited, require careful and regular attention. With a view to ensure this, it is usual to have a short code of printed regulations, which form a part of every agreement under which the separate offices are held. In one building, the internal organisation of which is well known to me, it is stipulated that a certain sum shall be paid, in addition to the rent for each room, for the office-cleaning and for coals; that the painting be renewed at fixed intervals, and that the charge for painting the passages and staircases be distributed among the tenants; that all window-cleaning shall also be done by the owner at fixed periods, and charged to the tenants; that all external blinds are renewed at stated periods at the tenants' expense; that no name-board, or plate, or other marks, are set up on the building, except with the owner's consent. The owner also provides, at the tenants' expense, a porter in plain livery, who acts as doorkeeper. All these arrangements insure a uniformity of appearance, and maintain a cleanliness and good order in the establishment, which has its value to the tenants, as well as to the owner, and prevents the confusion which would be inevitable in large establishments, if separate office-cleaners, &c. were allowed, and separate coal-stores kept.

INSTITUTION OF CIVIL ENGINEERS.

November 22.—During the Discussion upon Mr. Mann's Paper "*On the Decay of Materials in Tropical Climates*," a brief communication, on the same subject, by WILLIAM J. W. HEATH, was read.

During a residence in Ceylon, extending over a period of seven years, while engaged on the railway, Mr. Heath's attention had been directed to those materials which were most used in the construction of permanent buildings. The habitations of the lower class of natives were formed of a rude framework of stout bamboos, the sides and roofs consisting of reeds, closed in with the interwoven leaves of the cocoa-nut palm, the latter being washed over with the slimy juice of a native fruit, which, when dry, resembled copal varnish. In the huts built of "wattle and dab," the framework was made of roughly squared jungle trees, the space between being filled, and both the inside and the outside of the hut being covered, with clay and sand well kneaded, afterwards plastered over with earth thrown up by the white ants, mixed with a powerful binding substance produced by the ants. Superior houses were built of "cabook," a soft kind of rock, found at a few feet below the surface. This material had the appearance of a coarse sponge, the interstices being filled with soft clay. Before being used the blocks should be exposed to the rain, to allow some of the clay to be washed out. Cabook required to be protected from the weather, but if covered with a thin coating of lime plaster, it would last for years. Hard kinds of stone were not much used, owing to the expense of working them; and rubble masonry was not approved, as there was difficulty in obtaining even beds and good bond. Bricks as a rule were so badly burnt, and the clay was so badly pugged, that brickwork in exposed situations and unprotected would perish very rapidly. It was advisable that it should in all cases be well plastered with lime mortar. Two or three coats of boiled linseed oil would preserve brickwork without hiding it, but the expense prevented its general use. Coal tar was an excellent preservative, but on account of its unsightly appearance it could not be often employed. Lime was generally made by calcining white coral. When taken from the kiln it was in a fine white powder, fit for immediate use, after being mixed with twice its own bulk of sand and water. It set so rapidly that, in the Public Works Department it was the practice to keep the lime under water for two days before using it. This had the effect of making it longer in setting, but it was more easily worked, and eventually made better work, equal, in fact, to the best blue lias lime. Well-seasoned timber, with free ventilation, would endure for many years, if the white ants were kept away, without any precautions being taken to preserve it. In exposed situations, and where subject to the attacks of the white ant, Stockholm tar was the best preservative; while creosoted timber was free from their ravages. In sea water, and even in fresh water lakes and canals, timber was speedily attacked by worms, notwithstanding that it might be painted, oiled, or tarred.

Iron exposed to the influence of the varying weather speedily oxidised, but oil, applied hot, was a good preventive. Coal tar was, however, the best covering applied either cold or hot, or before or after oxidation had commenced. Ordinary galvanized sheet iron did not last many years, unless protected with good red lead paint frequently renewed; but zinc would last for many years with little or no decay.

In the course of the discussion it was stated that on the Great Indian Peninsula Railway, Baltic sleepers both creosoted and Kyanized, and native jungle wood sleepers had been used; but after thirteen years' experience, those which had failed were being replaced with teak and iron sleepers. The native woods were so hard and close grained that they could not be impregnated with any preservative substance. The keys were a source of great trouble in warm and variable climates. Those of wood had not been found efficient in India, and endeavours were now being made to devise a substitute. Iron work of all kinds should be thoroughly cleaned, dried by heat, and then dipped in hot linseed oil before being exported from this country.

It was contended that it was impossible to predicate what timber would sustain, for while yellow pine had been known to last sound, as railway sleepers for twenty-five years, in other cases it had decayed in five or six years. This frequently happened also with hard tropical woods, without there being any apparently assignable cause for this difference in the rate of decay. Hence, in the tropics iron was nearly the only material that could be employed especially for sleepers with anything like certainty as to the results. No doubt iron made a rigid permanent way unsuitable for the high speeds common in this country, although possibly this might be partially obviated by a more perfect manner of securing the rails on the sleepers; but in tropical climates the use of iron was almost a necessity, and there a speed of from 25 to 30 miles per hour was a maximum. Greaves' cast-iron bowl sleepers had been laid for eighteen years on the Egyptian railway, and made a good and substantial road. The objection that they were liable to break, particularly along the centre line, might be met by making them stronger; and it was remarked that on the Dom Pedro Segundo Railway, Rio Janeiro, the bowl sleepers had been in use for eleven years, and only one sleeper per mile had required to be renewed.

On the East Indian line, of more than 1000 miles in length, the sleepers were principally of sâl timber, but there were others of creosoted fir and of iron. Although there were many different kinds of suitable native woods, there was difficulty in obtaining large quantities of any other than sâl, which, when cut out of large timber and well seasoned, was very durable. Recently, in opening a part of the line near Calcutta, sâl sleepers had been found in a good state of preservation after having been laid twelve years. In other parts of the line, creosoted sleepers were in a serviceable condition after being in use ten years. Teak was perhaps the best of all Indian woods, but the cost precluded its use for sleepers, as it would amount to 15*s*. per sleeper. Flat iron sleepers had been unsuccessful, but cast-iron bowl sleepers seemed to promise better results, although at present they had not been sufficiently long in use to enable a definite opinion to be pronounced. The breakage so far had been serious, amounting to about 20 per cent., but this might be obviated in future by making them stronger, as had been suggested. The use of iron was desirable on account of the difficulty of obtaining large supplies of timber sleepers, and the uncertainty as to their quality.

Although the decay of materials in Ceylon was unquestionably influenced by the alternating effects of heat and moisture, yet it was believed to be principally due to the use of inferior materials. In the upper districts of India, there were brick and stone buildings of great antiquity, in fact anterior to historic periods. Sâl timber was hard, durable, and abundant in the central forests, and along the base of the Himalayas, and had been generally employed by the Public Works Department; but owing to the great demand of late years, it was now hardly possible to obtain it well seasoned. Teak was also becoming scarce; that which grew in the province of Burmah was of large size and very useful for shipbuilding; while when cultivated in a drier range and upon rocky ground it was as hard as ebony or iron wood, though of small scantling and of crooked form.

It was noticed as remarkable that the observations in one paper were repeated in the other, and that the means of preservation which had been suggested as applicable in Brazil, were likewise recommended for Ceylon. There were however some points of difference—especially as to the use of galvanized iron. The author of the first communication, speaking apparently from opinion rather than from experience, advised its use, while the author of the second, on the contrary, thought that galvanising alone, without painting or tarring, was not adequate to protect iron in such climates. As corroborative of the remark, that the loss of weight in iron from oxidation was less in Ceylon than in England, in an equal period of time, it was mentioned that out of a quantity of rails, which had been manufactured at the same time and at the same place, some were lying for many months unused in Ceylon, and others in South Wales, when the loss of weight by rust was found to be largely in excess at the latter place. Where there was great heat combined with excessive moisture, it was imagined that the effect upon materials, particularly timber, could not be otherwise than serious. While in the first instance it might be prudent to import timber artificially prepared, owing to the absence of available data as to the character of the native materials, yet it was believed, as the qualities of the different kinds of native woods became better known, as well as the proper time to fell them, and to prepare them by shed-drying or otherwise, and as a more ready access was obtained to the forests, native woods might ultimately be used with advantage and economy. In fact, a specimen of native Brazilian wood had been exhibited, which had endured for two hundred and fifty years. The alleged excessive wear of the rails and tires in Pernambuco must be explained upon other grounds than the heat. Perhaps the fact that the rails were not 'fished' until after a portion of the line had been opened for traffic, that there were considerable curves on the line, and that the road was not laid in the perfect manner which was possible in this country, added to the great atmospheric alternations, might be sufficient to account for it.

It was remarked that in using unprepared wood, no doubt it was desirable to select that part which was hard, as the pores being filled with ligneous matter, such timber did not so freely absorb moisture. But for creosoting purposes the reverse was the case, for it was impossible to make heart-wood absorb 10 lb. of oil per cubic foot, as was sometimes required. The great value of creosoting was that it enabled young wood to be used, as then, the pores being filled with a bituminous asphaltic mastic, the wood so treated was perfectly waterproof, and harder than heart-wood. The reason why the half-round sleepers on the Pernambuco line were more durable than those of square form, was believed to be due to all the young wood being retained in the former. Recent experiments in the harbour of Ostend showed that wood prepared with corrosive sublimate, or with sulphate of zinc or copper, was only partially protected against the worm, but when creosoted the worm would not touch it. It was advisable that piles in sea water should not be squared, but used round, with as much young wood as possible.

Respecting the ravages of the white ant, there were many old structures in Brazil not so affected; and as regarded railway sleepers, the frequent shaking and vibration would, it was considered, render them tolerably safe. In that country, porous and open-grained timber seemed most subject to these attacks; but in Australia the hardest kinds were first attacked. This was especially the case with iron-bark timber, the density of which was so great as to cause it to sink in water, and in tenacity and resistance to strain it approached rough cast-iron. White ants were effectually destroyed by oil of creosote, and anything of a bitter taste injected into the fibre, or even a small quantity of turpentine, would prevent their attacks. In some parts of India white ants were very destructive, and 10 per cent. of some stacks of sleepers had been decayed at the heart in from six to eight months. The black ants of the West Indies were also more destructive in hard than in soft wood. Some descriptions of wood there were, neither affected by the teredo navalis, nor by the black ant, and when used for piles had never been known to decay.

With regard to stone it had been found that the application of linseed oil not only acted as a preservative, but it rendered soft stone in the course of a short time very hard. In Jamaica the bricks were well made and of good materials; and some buildings there had stood from time immemorial without exhibiting any signs of decay. Mortar, both there and at the Cape was made of shell lime, and even when mixed with sea sand it was hard and durable. In India, the addition to the lime of about 5 per cent. of jaggery, a coarse native sugar, caused the mortar to set well and to be very durable. At the Cape the bricks were not good, and owing to the exudation of phosphate of soda after the work was finished, it was advisable to plaster all brickwork. In India the telegraph posts were to a large extent of stone obtained from Agra, and the rapid decay of timber when used for that purpose, had greatly retarded telegraphic extension in that country. The difficulty was now being met by making the lower parts of the posts of iron, into which wooden posts were inserted.

Respecting the statement that the only examples of iron bridges in the province of Pernambuco were those belonging to the railway, and that of St. Isabel, completed in 1863, it was remarked that about twenty years ago, a French engineer, M. Vauthier, when engineer-in-chief to the Province, designed and erected a suspension-bridge on one of the main roads, about nine miles from the city, across the river Capibaribe, at the village of Caxangà. The roadway, which was 100 feet long by 20 feet wide, was suspended from a pair of iron wire ropes on each side of the bridge by vertical rods of wrought-iron, the attachment of the rods to the ropes being by means of strong wrought-iron plates, embracing both ropes. Each rope was in four separate pieces, and consisted of a mass of wire simply laid together and bound at intervals. The rocking standards were of cast-iron in three pieces, and the platform was of wood. All the work was executed in the country, including the casting of the standards, but the wire was purchased in England. The ropes as well as the cast and wrought iron work were still sound. The cost had amounted to between £5000 and £6000.

November 29.—The paper read was "*Description of the Grimsby (Royal) Docks; with a detailed account of the inclosed land, entrance locks, dock walls, &c.*" By E. H. Clark.

The author stated that the old dock, formed from a natural creek, measuring in extent about 19 acres, was comparatively useless, by its shallowness and by the narrowness of the entrance channel. When the means of carrying out an extensive water commerce at the port of Grimsby were contemplated, the Manchester, Sheffield, and Lincolnshire Railway Company, who had become the proprietors of the old Haven and Dock, presented an extensive project to Parliament, designed by the late Mr. J. M. Rendel, C.E., which was sanctioned in the year 1845, and had since been completed. It comprised the formation of an entirely new dock, the entrances of which lay beyond the limits of low water, the new works being advanced into the river Humber for a distance of three-quarters of a mile, and embracing an enclosure of 138 acres of land reclaimed from the river. The works of this inclosure were commenced in the spring of 1846. They comprehended the construction of wharves, embankments, and a cofferdam, together nearly 1¼ mile in length. The cofferdam was remarkable for its magnitude, exposed position, and independent stability. Considerable difficulties were encountered in several places in obtaining a firm foundation for the wharves and embankments; but these were successfully overcome through the exertions of the late Mr. Adam Smith, C.E., the resident engineer, principally by loading the soft ground with chalkstone. The inclosure was completed by the end of the year 1848, when the interior works were commenced. These comprised the construction of a dock of 25 acres, with a depth of 6 feet at low water, and of 25 ft. 6 in. at high water, ordinary spring tides; of two entrance locks to the dock, the larger one being 300 feet in length between the pen gates, and 70 feet in width, and the smaller one 200 feet in length by 45 feet in width; and of a tidal basin of 13 acres inclosed by timber piers, with an entrance 260 feet in width. There were also extensive timber-ponds, a graving dock with a width of entrance of 70 feet, and on the quays, which were 3600 feet in length, transit-sheds and bonding-warehouses, granaries and cotton-sheds, cattle-pens and coal-spouts, with a railway passenger-station, and branch railways through the warehouses, besides a small dock for fishing-craft, 6 acres in extent, and having an entrance 20 feet in width, with the usual appurtenances connected with that trade. The contractors for the cofferdam were Messrs. Linn, of Liverpool, and for the dock works, Messrs. Hutchings, Brown, and Wright.

The cofferdam was 1500 feet in length, and consisted of two circular arcs, with a straight return on the west side, the versed sine of the curved portion being one-fifth of the span. It was situated where the average velocity of the tide in the river Humber was 5 miles per hour, and the rise of tide was 25 feet. There were three parallel rows of whole timber sheet piles of Memel fir, averaging 60 feet, 47 feet, and 37 feet in length respectively. The piles were driven in bays of 10 feet, and there was a space of 7 feet between the outer and the middle rows, and of 6 feet between the middle and the inner rows. Clay puddle was filled in between the rows. The tie-bolts connecting the rows of piles were arranged so as to break joint, to prevent a run of water directly through the dam. The chief novelty was, however, in the counterforts, or supports, placed at intervals of 25 feet along the whole length of the dam, and extending for 18 feet in depth, so as virtually to give the cofferdam a base of 32 feet in width. The counterforts were composed of whole timber sheet piles, and were firmly attached to the dam by wales and struts. The total quantity of timber used in the dam amounted to 709,000 cubic feet, and its construction occupied two years and a half. The wharf extended from the old dock entrance to the west end of the cofferdam, a length of 2431 feet, and from the east end of the cofferdam eastward for a length of 1208 feet, where it was joined by an embankment of 1800 feet in length. The wharf was constructed of a single row of whole timber sheet piles, with a dry rubble wall of chalkstone at the back, in the centre of which was a puddle wall. The embankment was composed of the stiff clay thrown up from the foreshore, and was faced with chalkstone on the seaward side, which had a slope of 5 to 1, while on the inland side the slope was 2 to 1. The two entrance locks were separated by a pier of masonry 70 feet in width. Each lock was provided with two pairs of pen-gates and one pair of flood-gates. The ground over the whole area of the locks, centre pier, and wing-walls, was excavated to a depth of 8 feet below the cill of the larger lock, and bearing piles were driven in rows, 5 feet apart from centre to centre, and in some places 4 feet apart from centre to centre, over this area. A pile was considered to be sufficiently driven, when it did not move more than one-quarter of an inch with a blow of a ram weighing 1 ton, and falling through 12 feet. The heads of the piles were then cut to a uniform level, the ground was removed to a depth of two feet below this level, and the space was filled up with concrete. Whole timbers, so connected as to form continuous ties across the locks and centre pier, were then laid transversely, in parallel rows, on the bearing piles. Other similar timbers were laid at right angles to the transverse bearers, concrete being filled in to the upper surfaces of these longitudinal bearers, which were then covered with planking, to serve as a bed for the masonry. Upwards of 254,000 cubic feet of timber, in addition to the sheet piles, were thus employed.

The masonry of the pointing-cells, gate-tables, inverts, aprons, platforms, square quoins and culverts, was of Bramley Fall stone; the hollow quoins of stone from the Calverley Wood quarries; while the backing to the walls was of chalkstone hammer-dressed, laid in regular courses, and well bonded with the ashlar. The inverts and platforms for the gates were wholly of stone; the cills were straight, and the joints of the masonry radiated horizontally and vertically, corresponding to the radius of the inverts. There were three main culverts—one in the centre pier, and one in each wall of the larger and smaller locks communicating with the dock, with branches and outlets to these culverts, for filling and emptying the locks, for scouring the entrance-channel, and for clearing the gate-tables.

From the treacherous nature of the ground on the site of the proposed dock walls, and from the necessity of obtaining good foundations for the granaries and transit-sheds, Mr. Rendel decided to form the walls of piers, varying from 40 feet to 80 feet in length, and generally about 6 feet thick, built of chalk-rubble masonry faced with ashlar, the space between the piers being arched over with brickwork. The backing of the walls consisted of a slope from the back part of the arch to the dock bottom, with a batter of 2½ to 1, composed of puddled clay faced with rough chalkstone. Blue lias lime from Lyme Regis was used in the preparation of the mortar. It cost, delivered at Grimsby, 10*s.* 6*d.* per ton. The mortar was of two kinds—the proportions of that employed for pointing and facework were ten parts of slacked lime, eight of screened sand, one part of forge ashes, and one part of pozzuolana. The other, used chiefly for the backing of walls and buildings, was composed of sixteen parts of slacked lime, twenty parts of screened sand, three parts of forge ashes, and one of pozzuolana. The cost of the former was about 16*s.*, and of the latter about 12*s.* per cubic yard.

The gates were of timber, chiefly of oak from the Black Forest, but teak and mahogany had been used. They were regular trussed girders, each pair of bars being trussed by wrought-iron straining-rods. Each leaf of the gates for the 70-feet locks weighed about 75 tons, and when completed, in 1850, they were considered to be the largest timber lock-gates ever made. It having been found on trial, when the large gates were being erected, that the ordinary roller fixed on the outside was out of the vertical plane passing through the centre of gravity of the gate, causing the gate, when moved, to twist considerably, it was determined to have two rollers, one on each side of the gate, but both to travel on the same path. The inner one was necessarily of smaller diameter than the outside one, and a cast-iron box was provided for the inside roller to fall into, when the gates were closed. There was a false door at the back of this box, and when any hard substance was forced against this door, a bar at the back was broken. During the twelve years these rollers had been in use, these bars had only required to be replaced about twelve times in the three pairs of gates The gudgeon, on which the heel-posts of the gates revolved, was of solid cast-iron, and the cup which fitted into the horn of the heel-post was of the same material, but in the top of the cup there was a piece of brass of a converse shape. The pointing cills of the gates were straight, and corresponded with the bottom bars of the gates. They were protected by cast-iron face-plates, jointed and planed so as to form a perfectly water-tight joint. The cost of a pair of gates for the larger lock, 70 feet wide, was £2300, exclusive of the machinery for working them. This was the first instance of the application of Sir W. G. Armstrong's hydraulic machinery for opening and closing lock-gates, and its cost for the six pairs of gates in both locks was about £4000, including foundations and cast-iron pits for the chains to work in. Two men only were required to work the gates of both locks, which could be opened in two minutes and a half, and the machinery, which had now been in use for ten years, had required very few repairs, and had answered admirably.

The piers forming the boundaries of the tidal basin were of open timberwork constructed in bays of piles in clusters, each bay being 25 feet apart. The whole of the timber had been thoroughly creosoted at the rate of 45 gallons of oil per load of timber. The channel from the mouth of the basin to the entrance locks averaged 260 feet in width, and was kept to the level of the lock cills by frequent scouring, and by occasional dredging. Immediately outside the tidal piers the channel was 3 feet below the level of the larger lock cills, and the scour of the tides past the pierheads had gradually deepened the channel, since the construction of the dock works, from 3 to 4 feet. In addition to the means provided for sluicing the silty deposit from the channel of the tidal basin, the back water from the country, which originally flowed into the old dock channel, was now diverted into the tidal basin.

A graving-dock had been constructed since the opening of the new docks, with a width of entrance of 70 ft., the cill being laid at the level of 6 feet above the cill of the larger lock. giving an average depth of water of 19 ft. 6 in. The length of the dock for keel was 350 feet, the width of the floor was 52 feet, and at the level of the coping 96 feet, tapering to 84 feet at the ends. The area of the dock was surrounded by a row of Memel fir sheet piles; and rows of piles were driven in the centre line of the dock, to support the weight of the ships when blocked. The ground within this area was removed to a depth of 6 feet, and was replaced by concrete. The inverts and gate-tables were of Bramley Fall stone, and the joints were radiated both vertically and horizontally. The floor was curved, instead of concave or flat, as was the usual plan; thus giving greater space for the workmen, and allowing of better ventilation round the sides of the vessel. The sides of the dock were in nine steps, each step being 3 feet in height, with a width of tread of 3 feet. The graving-dock was supplied with water direct from the Royal dock, and was drained to the level of low water into the tideway; but as the floor of the dock was 3 feet below the level of low water of ordinary spring-tides, a depth of water of from 3 feet to 4 feet had to be removed by pumping. This was effected by a centrifugal pump, supplied by Messrs. Simpson, fixed in a well adjoining the dock, and its cost complete, including pipes and erection, was £413. These pumps were deemed to be very suitable for the drainage of graving-docks, as they were not liable to become choked like valve-pumps, from the chips and rubbish which found their way into the well. The gates were of oak timber, and were similar to those of the locks, 70 feet wide. They were, however, worked by powerful double-purchase crabs, instead of by hydraulic machinery, as being so seldom used in comparison with lock-gates, it was considered that this plan would be less expensive. The total cost of the graving-dock, including the engine-house and well, but not the engine and pumps, was £32,000. It was designed by Mr. Adam Smith, and was constructed, under the superintendence of the author, by Mr. J. Taylor. Two lines of railway, laid on a timber staging, ran into the dock, having coal-spouts at their extremities. These spouts, or wrought-iron shoots, were fitted with hinged joints, and were capable of being raised or lowered by winches to the height of the deck of the vessel. There were doors in the bottoms of the coal-waggons, and breakage of the coal was in a great measure prevented, by a door being fixed inside the spouts, hinged to one of its sides, and connected by a chain with a winch above, by which the rate of the coal entering the vessel was entirely under control. The waggons, when emptied, descended by their own gravity down the return line. About 400 tons of coal per day could be loaded at each spout.

A tower, having a total height of 300 feet, was erected, and in this, at a height of 200 feet, a wrought-iron tank was fixed, capable of holding 33,000 gallons, for the purpose of serving as an accumulator of water-pressure for working the machinery of the lock-gates and cranes, and of supplying fresh water to the shipping. The water was forced into the tank by two pumps, each 10 inches in diameter, worked by a duplicate horizontal engine of 25 H.P. The engines, pumps, pipes, and machinery, were supplied by Sir W. G. Armstrong.

In concluding the paper the author remarked that he had observed, for several years past, that there was a gradual wasting away of the promontory on the Yorkshire coast, opposite the Grimsby, known as the Spurn Point. On the maintenance of this Point depended, he believed, the existence of Grimsby as a port. About eight or nine years back, when the sea threatened to make a breach between the Spurn Point and the mainland, Mr. Rendel directed the attention of the Government to the matter, and the foreshore of this neck of land was then protected, by depositing on it large quantities of chalkstone. Since then nothing had been done, and it was now to be feared, unless immediate steps were taken, that a permanent breach might be made, and the channel of the river Humber be diverted from the Lincolnshire coast, and form for itself a new outlet into the North Sea, when the channel opposite the Grimsby Docks would probably be silted up.

Dec. 6.—The paper read was "*Description of the River Tees, and of the works upon it connected with the navigation*" by JOSEPH TAYLOR, A.I.C.E.

"After describing the course of the river from its rise in the south-eastern flank of Cross Fell, in the Goredale series of carboniferous limestones, and the geological features of the country through which it passed, the author alluded to the works above Darlington for supplying that town, as well as Stockton-on-Tees and Middlesbro', with water. But neither at these works, nor elsewhere, so far as the author was aware, had any gaugings been taken, with sufficient accuracy to be of value. The tide flowed as far as Yarm, and the river was navigable to that town for small vessels. At Stockton-on-Tees, seven miles further, the river assumed considerable dimensions, and vessels of from 200 to 300 tons burthen came up to its quays. Thence to Middlesbro', five miles, its course was very tortuous, and immediately below, after making a sudden bend to the north-east, it opened into a wide estuary, upwards of three miles in width from shore to shore; but of this a large area was only covered to the depth of a few inches at high water. The bar buoy was about eight miles below Middlesbro'. The total length of the course of the Tees was between 70 and 80 miles, and its basin contained an area of about 750 square miles.

Under an Act obtained in the year 1808, a cut was made from the east side of the river near Stockton, through a neck of land to Portrack. This channel was 220 yards in length, and it shortened the course of the river about 2¼ miles, producing a scour by which the depth of water at Stockton Quay was increased from 9 feet to 11 feet. The cost of this work was upwards of £12,000. A second cut was completed in 1830, from Blue House Point to near Newport. This was 1100 yards in length, and cost about £26,000. About the same time, the construction of timber jetties or groynes, at right angles to the stream was commenced. Their total number at present was forty-three, and they varied in length from 40 feet to upwards of 2000 feet.

Allusion was then made to the staithes for shipping coal, erected on the bank of the river at Middlesbro'; and it was stated that, owing to the shipping berths at the staithes having become filled up, a ship of the usual draught of water could with difficulty be unloaded. In 1842 therefore a dock was constructed, and the staithes were abandoned.

Having noticed the principal works connected with the navigation, the author next referred to their effect on the channel of the river. The first cut, of 1808, appeared to have been well devised, for it contributed to the removal of a shoal lying a little higher up the river, and produced an increased depth of water of 2 feet at Stockton Quay. The expediency of the second cut was more doubtful, as it destroyed a broad reach of the river, thus depriving the channel below of an important reservoir of tidal water. The combined effect of the timber groynes and of the two artificial channels had been to reduce the river between Stockton and Newport to a nearly uniform width, straight and narrow, through which the ebb tide flowed with considerable velocity. As the tide was suddenly checked at the eastern extremity of the second cut by the greater width of the channel, the tendency was for all matters held in suspension to be deposited, thus forming shoals, and filling up the bed of the river. As this was constantly recurring, the system of groynes had been continued lower down with a view to secure deep water, and when the wider channel was reached, it became more difficult to deal with it.

The works had caused the silting-up of the north shore of Bamblet's Bight, which must have been contemplated; but they also led to the filling up of the shipping berths at Middlesbro', which could not have been intended. In 1852, the control of the river was assumed by the present Thames Conservancy Commission. For some years previous, the river below Middlesbro' had been in a very bad state, and was continually getting worse. It was evident by letters from shipowners, as given in Mr. Bald's report to the Admiralty in 1861, and was corroborated by the personal experience of the author, that the channel changed very much every spring tide, by the operation of the jetties below Cargo Fleet, and that it ran almost dry at low water near the ninth buoy. In fact, the effect of the groynes had been to advance the foreshore to their extremities; and in many cases the width of the original channel in the Tees had been reduced one-half, by which a large body of tidal water had been excluded, reducing the velocity of the ebb tides, and diminishing the scouring force, with a corresponding result in the lower reaches of the river. In 1821, previous to the construction of any of these works, the least depth of water btween Cargo Fleet and the ninth buoy anchorage was 6 feet, excepting upon the Mussel scarf shoal, since removed by dredging; and which it was estimated by Mr. Bald, in his report to the Admiralty, might have been then effected for £350, while the cost of the jetties, which did not remove it, must have been considerably greater. The works in the upper part of the river had therefore reduced the depth in the channel below Middlesbro' 4 feet and the deep water anchorage berths had also been considerably diminished. It was not doubted that the channel of the river between Stockton and Middlesbro' had been made more direct, and the depth more uniform, by the construction of the various works; but the author was of opinion that better results would have been obtained by a judicious system of dredging, and that the disastrous effects upon the lower reaches of the river might have been avoided. The author believed, as a general principle, that the operation of dredging, by lowering the bed of the river, and thus increasing the tidal flow, was acting in unison with the natural scouring forces; whilst contracting the channel, by jetties or groynes, shut out a corresponding amount of tidal water, and weakened the scouring force of the ebb tide.

In conclusion it was stated that the new commissioners had principally directed their attention to dredging the channel and to forming groynes or training walls of refuse slag from the iron works, either at half tide level or at low water mark, in place of the old timber jetties, by which the depth of the channel had been increased to upwards of 4 feet at low water. A breakwater, also of iron slag, was now in process of construction near the mouth of the Tees, on the southern shore, extending for a distance of about 4300 yards; and it was intended to form another pier from the north shore for a length of about 2000 yards. The ends of these two piers would curve seaward, leaving an entrance channel of 600 yards in width. It was hoped that by the construction of these piers, a safe and sheltered harbour of refuge would be created at the mouth of the Tees. The depth on the bar at low water spring tides was about 11 feet, and at high water 27 feet, being a greater depth than existed on the bars of the Tyne, the Wear, or the Clyde."

December 13.—After the meeting, Mr. F. B. Doering exhibited and explained a Level, which for readier adjustment, was supported upon a gimbal joint, instead of on parallel plates; and he stated that the plan was applicable to other surveying instruments. The method was similar to that adopted for a ship's compass, with the addition of vertical arcs at right angles to each respective axis, which were clamped to each other and to the frame that was screwed on to the ordinary tripod stand. In the field, when using this instrument, however uneven the ground might be, the legs were put down in the most convenient manner, irrespective of level. The clamps holding the telescope rigid with the stand were then slackened, and the telescope set approximately level by the hand. The clamping screws were then tightened, and the final adjustment effected by two tangent screws at right angles to one another, and connected respectively with each arc at the clamps. On moderately level and firm ground, it was not necessary to unclamp the joint of the instrument; as it might be set up approximately level in the ordinary way by the legs, and be brought to a perfect adjustment at once by the tangent screws. By dividing one of the arcs into degrees the instrument could be used for measuring vertical angles, and thus the height of any point at a distance, required for checking, might be obtained. It was believed that by this method, a level could be set up on sidelong, soft, or broken ground, and with as much ease as on firm, level ground; and that, as none of the moveable parts were liable to become jammed, as in the parallel plate system, a more perfect adjustment was practicable. A level constructed in this manner had been tried in wet weather and in highwinds, and proved to be as steady as any instrument hitherto made.

Annual General Meeting.

Dec. 20.—In presenting an account of the proceedings during the past twelve months, the council reported that the characteristic feature of steady progressive development was never more fully exemplified in any similar period, since the first establishment of the institution. The meetings had proved very attractive, the discussions had been well sustained, the library was fast becoming rich in all professional and scientific works of this and other countries, the number of members and associates had greatly increased, and the financial condition was very satisfactory. The importance to engineers of being connected with the institution was felt more and more every day; and although the time had not yet arrived when it was considered imperative for every one practising the profession to have received the diploma of the institution, yet in general opinion it might fairly be said that that position had been attained. On these grounds, therefore, it was more than ever essential that the qualifications of all candidates for admission should be most scrupulously examined; and that the members should satisfy themselves, before signing any proposition paper, that the person so recommended possessed such character, practice, and experience, as to entitle him to the distinction he sought.

There had been twenty-three ordinary general meetings during the session, when eleven papers had been read, many of the evenings having been entirely occupied by discussions. The communications related to the details of erection of three Lighthouses for facilitating the navigation of the northern portion of the Red Sea; to the causes of the decline in the duty of Cornish Pumping Engines; to the circumstances which determined the velocities of influx and reflux, and consequent scour, attendant on the final closing of embankments for reclaiming land from the sea, or from a tideway; to a description of the features of, and changes in, that portion of the East Coast of England between the Thames and the Wash Estuaries; to the actual state of the works in the Mont Cenis Tunnel, perhaps the most important and interesting work of civil engineering in the present day; to an inquiry into the resistances to bodies passing through water; to the Santiago and Valparaiso Railway; to the structure of locomotive engines for ascending steep gradients, when in combination with sharp curves, and to the impedimental friction between wheel tires and rails; to the distillation of coal and the manufacture of coke; and to the machinery employed in sinking Artesian wells on the Continent.

With regard to the publication of the Minutes of Proceedings, it was stated that volumes xxi. and xxii. would shortly be issued, and that the General Index to the series of volumes from i. to xx. inclusive, in itself a volume of about four hundred pages, was also nearly ready.

A new edition of the Catalogue of the Library was in preparation, in continuation of that issued in 1851, now out of print. At that date the library contained upwards of three thousand volumes and fifteen hundred tracts; now the collection amounted to about five thousand five hundred volumes and three thousand tracts.

The tabular statement of the transfers, elections, deceases, and resignations, showed that the number of elections had been 93, of deceases 25, of resignations 6, and of erasures 7, leaving an effective increase of 55, and making the total number of members of all classes on the books, on the 30th of November last, 1095. This was an increase of nearly 5·3 per cent. in the past twelve months.

The deceases announced during the year had been:—Francis Baird, Thomas Bartlett, John George Bodmer, Thomas Casebourne, Charles Dean, Joseph Gibbs, George Hurwood, James Jones, Rhys William Jones, Edward Oliver Manby, George Meredith, George Mackay Miller, William Chadwell Mylne, Richard Roberts, William Simpson, and Adam Smith, members; John Staines Atkinson, William Bagnall, Frederick Lawrence, William Llewellyn, Thomas Telford Mitchell, Robert Ransome, Charles Frederick Stuart Smith, Alfred Thompson, and Arthur Wightman, associates.

This list included the names of many very old members, several of whom had been engaged under the first President, Telford, as well as one of the six founders of the institution—Mr. James Jones—who in its early days acted as Secretary, and whose death, at an advanced age, was the result of a lamentable accident.

The abstract of the receipts and expenditure, for the year ending the 30th of November last, as prepared by the auditors, showed that the payments during the twelve months had amounted to £2955, against receipts from all sources of £4414; and that the amount obtained from subscriptions and fees alone, without including the dividends upon investments, and the sums derived from other sources, had exceeded the disbursements by about £450. The Council had, therefore, been again enabled to add to the Institution Fund, by the purchase of £1000 Four-per-Cent. Debenture Stock, of the London, Brighton, and South Coast Railway Company. On comparing this statement of accounts with the average of the previous ten years, it appeared that the total income now exceeded that average by nearly 40 per cent., while the increase in the disbursements, during the same period, had been less than 20 per cent. The realised property of the institution now comprised:—I. General Funds, £10,819. 12*s*. 10*d*.; II. Building Fund, £1751. 0*s*. 1*d*.; and III. Trust Funds, £9970. 12*s*. 7*d*., making a total of £22,541. 5*s*. 6*d*., as against £20,649. 16*s*. 2*d*, at the same period last year.

The propriety of establishing a Benevolent Fund in connection with the profession received the serious consideration of the Council before any steps were taken to ascertain the views of the members generally. It was well pointed out by Mr. F. J. Bramwell (M. Inst. C.E.), with whom the present proposal originated, that in most, if not in all, other professions and occupations there was a regularly organised system for the aid of decayed members, and of the families of deceased members, when in necessitous circumstances; and that, inasmuch as the civil engineers already formed a numerous and increasing body, in some respects more liable to those misfortunes and vicissitudes which were known by experience to overtake those following other pursuits, it was incumbent on the profession that some business-like action should be taken, in preference to soliciting subscriptions for individual cases, now unfortunately found to be frequently requisite. Private inquiries among a few of the members of the institution having shown that such a fund, if properly managed and adequately supported, could not fail to be productive of immense good, it was determined to appeal to the general body, and the result had been such a response as fully to justify the course which had been pursued. Already from 224 contributors, donations to the amount of £21,884, and annual subscriptions to the extent of £487, had been promised. Of these contributors, 97 were donors only, 14 were both donors and annual subscribers, and 113 were annual subscribers.

At the meeting recently held in the rooms of the institution, the fund was formally established, and that portion of the general committee, which it was recommended should be elected by the contributors, was appointed. At the same time the committee was requested to prepare a scheme, with bye-laws and rules, for the administration of the fund, and to report the result of their deliberations to a general meeting of the contributors, to be summoned for the 17th of January next. The council would not venture to anticipate what might be the issue of the considerations of the committee, but they felt assured that a measure so calculated to enhance the character of the profession would be cordially supported; and on every ground they commended it to the most favourable notice of the members.

If the object of the profession of a civil engineer be, as described in the charter of incorporation of the institution, "the art of directing the great sources of power in nature for the use and convenience of man," it might fairly be asked, what other profession played so large a part in developing the material resources of the world, and in facilitating that intercourse between nations which tended to promote peace and good will. It should then, be the constant endeavour to make the institution the depository of the accumulated knowledge of all the members; and all should strive so to sustain and consolidate the institution, that it might continue truly and faithfully to represent the important interests committed to the care of the civil engineer.

After the reading of the report, a Telford medal and a Telford premium of books were presented to Mr. W. Lloyd; a Telford medal to M. Pernolet; a Telford medal and the Manby premium, in books, to Mr. G. H. Phipps; Telford premiums of books to Messrs. J. B. Redman, W. Parkes, T. Sopwith, junior, J. M. Heppel, and G. R. Burnell; and Watt medals to Messrs. T. Sopwith, junior, W. Bridges Adams, and J. Cross.

The thanks of the institution were unanimously voted to the President for his attention to the duties of his office; to the Vice-presidents and the other members and associates of council for their co-operation with the President, and their constant attendance at the meetings; to Mr. F. J. Bramwell, as the originator of the present movement for the establishment of a benevolent fund in connection with the profession; to Mr. Charles Manby, Honorary Secretary, and to Mr. James Forrest, Secretary, for the manner in which they had performed the duties of their offices; as also to the auditors of the accounts, and the scrutineers of the ballot, for their services.

The following gentlemen were elected to fill the several offices on the council for the ensuing year:—John R. M'Clean, President; J. Fowler, C. H. Gregory, T. Hawksley, and J. S. Russell, Vice-Presidents; Sir William Armstrong, W. H. Barlow, N. Beardmore, J. Cubitt, T. E. Harrison, G. W. Hemans, J. Murray, G. R. Stephenson, C. Vignoles, and J. Whitworth, members; and John Aird, junior, and A. Ogilvie, associates.

ON THE APPLICATION OF IRON TO THE PURPOSES OF NAVAL CONSTRUCTION.

By W. Fairbairn, LL.D., F.R.S.

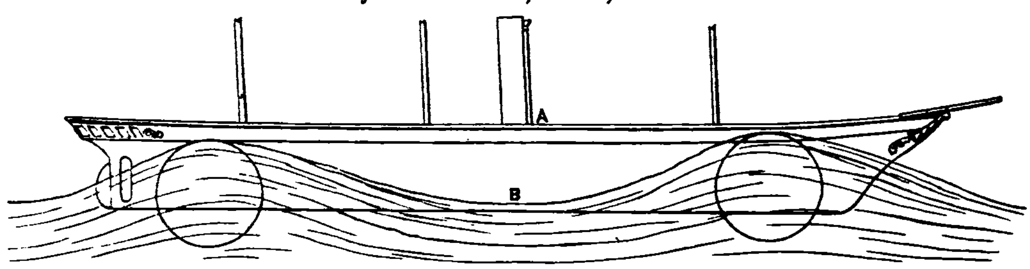


Fig. 1.

3. On the Resistance of Plates, as applied in different Forms to the Force of Compression.—We have already noticed, when treating of the tensile strain to which a ship is subjected, that another equally important force is in operation in the movements of the vessel—that of crushing or compression. This is more apparent in iron than in wooden structures, as thin plates are liable to distortion when forcibly compressed in the direction of their lengths; and in shipbuilding, as in tubular girder bridges, this tendency to "pucker" requires to be carefully guarded against. When conducting the experiments for the Conway and Britannia bridges, this weakness was strikingly apparent, and was carefully considered; and as the strains in that of a ship and a monster tubular girder are analogous, it is necessary in both structures that the resistance should be clearly understood, the two forces nicely balanced, and the tendency to buckle prevented.

To enable the practical shipbuilder to acquire this knowledge, and become acquainted with the laws which govern iron structures of different forms, it will be necessary to investigate this question attentively, and endeavour to establish sound principles of construction in the minds of those who are intrusted with designs of such great public importance.

To construct a perfectly secure iron ship, every one of the transverse joints should be planed, in order that the ends of the plates may butt, and form a solid joint. This connection is the more important, as the action of a vessel pitching at sea is a continued series of alternate strains of tension and compression.

This motion is the most violent to which a vessel afloat is subject, and it is the most injurious to the structure. A vessel of war covered with armour plate, or a mercantile ship with a heavy cargo, plunges heavily at sea, and the waves meet her with violent shocks, so much so as to slacken her speed, and cause her to tremble or vibrate on the crest of the waves. This motion is somewhat analogous to that of rolling, but much more severe, as that part of the vessel which is left unsupported acts as a weighted lever on a transverse axis through the ship's centre of gravity, and thus produces severe strains at midships. By extending the weights or cargo in the direction of the bows and stern, these strains are increased, and this, as a general rule, should be avoided by concentrating the cargo as much as possible at the centre of the ship.

Let us suppose a vessel in the middle of the Atlantic or Pacific Ocean having to encounter a rolling sea in a storm, where the elevation from the trough to the crest of the wave is 24 feet, and the distance from point to point 380 to 400 feet; and supposing that these waves move at a velocity of 10 knots an hour, and we have a vessel (as represented in Fig. 1) with two waves, one at the bow and and another at the stern, and her midships partially unsupported, as if two liquid rollers (if I may be allowed the expression) were passing under her bottom. In this position the strains would have a tendency to crush the material composing the upper deck at A, and to tear asunder the hull or bottom B. Hence the necessity for increased resistance in those parts. Reversing this position, and supposing that the liquid rollers or waves have passed from the bows and stern to the centre of the

* Continued from vol. xxvii. Page 347.

ship, and we have her balanced in the shape of a scale-beam, as at Fig. 2, with both ends only partially supported. In this position the strains are reversed, and we have the crushing force along the bottom as at B, and the tension or tearing force pulling at A on the upper deck. Assuming, again, that the wave has passed from the centre of the vessel half-way to the stern, and we have the same forces continued—namely, the maximum of tension on the upper deck at the point A, immediately over the apex of the surge, and compression at B below (Fig. 3).

In these forms we have nearly all the disturbances and variety of strains, independent of rolling and wrenching, to which vessels are subjected when afloat. Under other circumstances, such as a vessel stranded on a lee shore, beaten on rocks or sandbanks, similar forces of much greater intensity come into operation, and the only safeguard in these conditions is increased strength at midships, and a sufficient number of water-tight bulk-heads, dividing the ship into five or six different compartments.

From the above it will be seen that alternate strains of varying intensity are continually in action during the time the vessel is plunging at sea with the whole of her cargo on board.

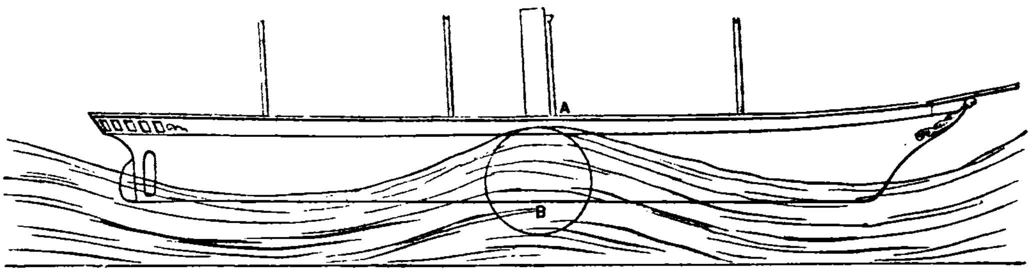
On the question of the strength of iron ships, we could not have a more striking illustration of the disastrous effect of defective construction, than that which took place in the case of the Montreal Ocean Mail steamer Jura, only a few weeks ago, which, by some mistake of the pilot, ran upon the Crosby-spit, a narrow sandbank at the entrance of the Mersey. She was running full speed at the time. The forepart of her keel became fixed on the bank, the stern hanging in deep water, and the result was she parted amidships (as shown in Fig. 4), entirely for want of a judicious application of iron stringers on each side of the upper deck, calculated to balance the area of the hull at amidships, and to resist the force of tension which tore her asunder on the upper deck.

On this very important inquiry of alternate strains, we are fortunate in having before us a series of experiments on the endurance of iron-jointed beams subjected to these changes. Not exactly similar to that of a steam-engine beam, but a less severe test, arising from alternately reimposing and removing the load. This, it will be observed, was simply a constant change of tensile force in one direction, and compressive on the other, whereas that of a ship is subject to both tension and compression on the bottom and upper deck as she rises and falls upon the waves.

On referring to the experiments to which we have alluded, we arrive at this curious and interesting fact, that the joints of an iron rivetted beam sustained upwards of 1,000,000 changes of one-fourth the weight that would break it, without any apparent injury to its ultimate powers of resistance. It, however, broke with 313,000 additional changes, when loaded to one-third the breaking weight, evidently showing that the construction is not safe when tested with alternate changes of a load equivalent to one-third the weight that would break it.

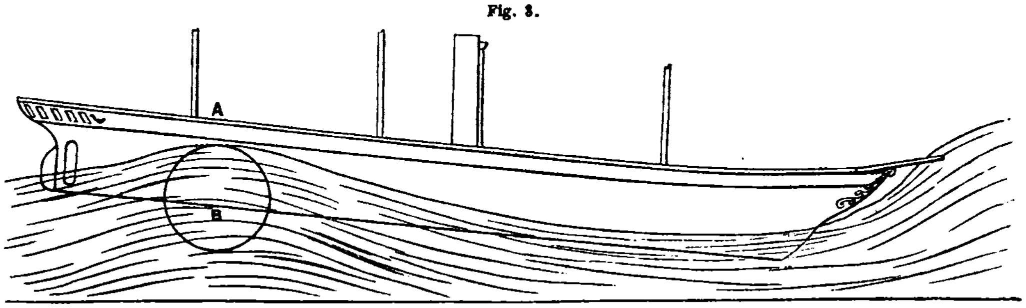
These results are probably not without interest as regards the construction of iron vessels, as they appear to be conclusive that time is an element in the endurance of structures when subjected to severe strains affecting their ultimate powers of resistance. It is difficult to determine or pronounce what is the correct measure of safety, whether one-fifth or one-fourth the breaking weight, but we have sufficient data to be assured that every disturbance, however minute, in the molecular construction of bodies finally tends to their destruction, and it is only a question of time when rupture ensues. We may, however, be assured that a ship, as well as a beam, is practically safe for a long series of years, when the strains do not exceed 5 tons per square inch upon the wrought-iron plates of which it is composed.

Fig. 2.



Dr. Rankine has investigated this question, and in a paper read before the mechanical section of the British Association for the advancement of Science at Bath, entitled, 'On some of the Strains of Ships,' he states, that in previous scientific investigations respecting the strains which ships have to bear, it has been usual to suppose the ship balanced on a point of rock, or supported at the ends on two rocks. The strains which would thus be produced are far more severe than any which have to be borne by a ship afloat. The author computes the most severe straining action which can act on a ship afloat—viz., that which takes place when she is supported midships on a wave crest and dry at the ends; and he finds that the bending action cannot exceed that due to the weight of a ship with a leverage of one-twentieth of her length, and the racking action cannot exceed about sixteen one-hundredths of her weight. Applying these rules to two remarkably good examples of ships of 2680 tons displacement, one of iron and the other of wood, described by Mr. John Vernon, in a paper read to the Institution of Mechanical Engineers in 1863, he finds the following values of the greatest stress of different kinds exerted on the material of the ship:—In the iron ship—tension, 3·98 tons per square inch; thrust, 2·35; racking stress, 0·975. It follows that in the iron ship the factor against bending is between 5 and 6, agreeing exactly with the best practice of engineers, and that there is a great surplus of strength against racking. In the wooden ship—tension, 0·375 tons per square inch; thrust, 0·293. Here the factor of safety is between 10 and 15, which is also agreeable to good practice in carpentry. As for the racking-action, the iron diagonal braces required by Lloyd's rules would be sufficient to bear one-third of it only, leaving the rest to be borne by the friction and adhesion of the planking.

Fig. 3.

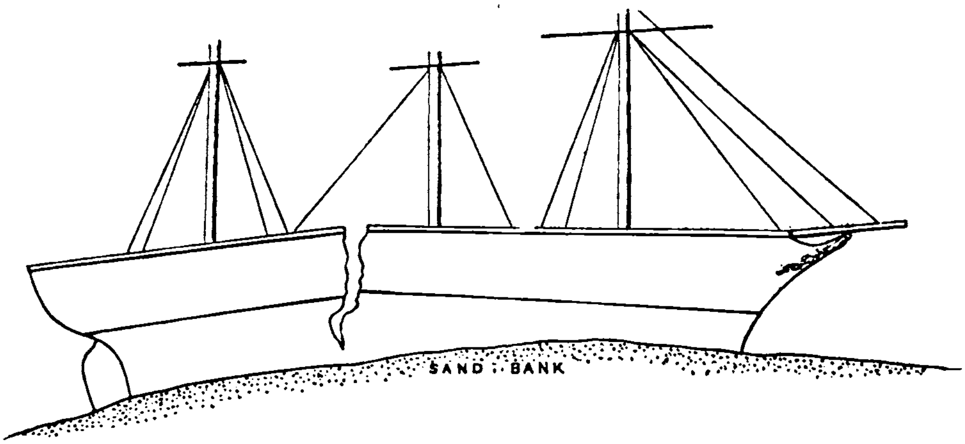


From these inquiries it would appear that the strains are considerable on an iron ship—that for tension being 3·98, or 4 tons per square inch; thrust, or compression, 2·35 tons; and racking stress, 0·975 tons;—evidently showing that a ship labouring at sea is subject to severe tests of repeated strains, independent of shocks which may occur from displacement of cargo or waves of greater magnitude, which generally succeed each other at certain intervals in severe gales. But be this as it may, it is necessary to have iron ships securely and strongly built.

FLEXURE AND CRUSHING.—It has been ascertained that the effect of compression on any substance is to shorten its height, and to enlarge its surface by increasing its bulk horizontally. Supposing, however, that the substance is confined and prevented from spreading in that direction, and it will then be found that the weight of one ton compresses wrought-iron about one ten-thousandth part of an inch; and in cast-iron, which is much harder, we meet with this anomalous condition—namely, that a similar specimen is shortened or compressed two ten-thousandth parts of an inch, being double that of wrought-iron, with the same weight. This arises, probably, from the porosity of its crystalline structure as compared with wrought-iron, which undergoes a process of consolidation by hammering and rolling.

Another curious circumstance connected with wrought-iron, when submitted to compression is, that it will bear any amount of pressure, provided that it be sufficiently ductile. It, however, absolutely necessary, to keep within the limits of its elasticity.

We have already seen that both the top and the bottom of a ship have to resist a force of compression analogous to that sustained by columns, and that being the case, it is desirable that we should become acquainted with the resistances of wrought-iron of different forms in that direction. It is also necessary to ascertain the laws by which these resistances are regulated in the relative positions of the upper deck and the lower hull of a ship. Effectively to resist these forces, it is obvious that the covering plates below, and the stringer plates above, require to be stiffened, or in other words, to convert them into a series of horizontal pillars, calculated to offer an equally powerful resistance to compression as they do to tension. It was for that object that the late Prof. Hodgkinson undertook—in conjunction with the writer, when engaged in the construction of the Britannia and Conway bridges—a laborious series of experiments on the compression of wrought-iron plates and tubes, which form the top of these immense structures. These experiments apply with equal force to



suffers distortion by a comparatively light weight, and its resisting powers are seriously injured with 12 tons per square inch. Beyond this, it may be compressed to any extent, provided it be sufficiently plastic, by enlarging its base and shortening its height till it becomes a perfectly flat plate. With 12 tons its elasticity is much impaired, and it takes a considerable permanent set, which increases as the square of the load; and in most cases, where these effects are important, it is very desirable, if not the construction of iron ships as they do to tubular bridges, and we may find it serviceable to offer a few remarks upon them.

In the earlier experiments it was found that round, square, and rectangular tubes of a given length, presented nearly double the resisting powers when the same weight of material was applied in the form of a tube or cell, than it did in the form of a solid plate. These facts were subsequently confirmed by Prof. Hodgkinson's experiments, of which the following is an abstract:—

Resistance of Rectangular Tubes, all Ten Feet long, to a Force of Compression in the direction of their length.

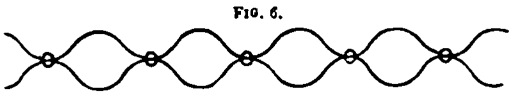
External dimensions of tube.	Thickness of plates.	Weight with which buckling or perceptible undulation was observed.	Weight of greatest resistance.	Form of section of tube.	Area of section of tube.	Weight per square inch of greatest resistance.
inches.	inches.	lbs.	lbs.		inches	tons.
4·1 × 4·1	03	...	5,534		·5040	4·9020
4·1 × 4·1	·06	...	19,646		1·0200	8·5986
4·25 × 4·25	·083	29,290	37,354		1·4840	11·2370
4·25 × 4·25	·134	46,314	51,690		2·3947	9·6360
8·175 × 4·1	·061	13,209	23,289		1·532	6·786
8·5 × 4·75	·264	...	197,163		7·326	12·015
8·4 × 4·25	·26 & ·126	99,916 (?)	206,571 = 92·2 tons.		6·89 (nearly)	13,3845
8·1 × 4·1	·059	37,401	43,673		1·885	9·877
8½ × 4¼	¼ (nearly)	...	...		8·3466	Not crushed with 11·12 tons
8·1 × 8·1	·06 (nearly)	15,897	27,545		2·070	5·926
8·37 × 8·37	·189	82,475	100,395		4·9262	9·098
8·5 × 8·375	·2191	...	198,955		7·7367	11·48
8·5 × 8·4	·245 & ·238	..	...		8·4665	Not crushed with 11·05 tons
8·1 × 8·1	·0637	56,630	70,070		3·551	8·809
8·1 × 8·1	·0637	46,635	82,027		3·551	10·812

A plate employed as a pillar resists flexure in a much higher ratio than in the simple proportion of its thickness, such stiffness or strength being analogous to the transverse stiffness of a beam; hence, as in the beam, it will also be highly advantageous to distribute any given material in a pillar, in such a manner as to insure the greatest possible depth in the direction in which it is liable to bend. Mr. Hodgkinson states, that if the pillars are short as compared with their diameter, such precautions are unnecessary, the cubic inch of wrought-iron cannot be put in better form; but if it were rolled into a very long and very thin plate, 1 inch broad, and placed on edge, the smallest force would bend it. If we shorten this thin plate by increasing its thickness, but maintaining the same height of 1 inch, we shall increase its resistance to flexure in proportion directly to the cube of the thickness, and in proportion inversely to the length, since the length will diminish in the same proportion as the thickness increases, therefore the strength will increase directly as the square of the increasing thickness, or inversely as the square of the decreasing length, until the plate arrives at such a thickness that it will fail partly by crushing. This law will now begin to vary as we go on increasing the thickness at the expense of the length; and ultimately, as we approach the cube itself again, the strength, instead of varying as the square of the increasing thickness, will cease to vary at all with the thickness; its strength will therefore have varied during these changes, as every power of the thickness between 0 and the square of the thickness, while the resistance itself would be represented progressively by every quantity between 16 tons and 0, the quantity of material or section and height having remained constant, so that n square inches of sectional area on the top of a tube may resist any compression between 0 and $n \times 16$ tons, according to the form in which it is applied. We should thus use the thickest plates we can get for the top of a ship or a tube, until their thickness was such that any variation in the thickness causes no corresponding variation in their resistance to compression; beyond this we get no further advantage. If, however, we are compelled to use thin plates, we should arrange them so as to insure depth to resist buckling. If one cubic inch, when rolled out into a long strip, so as to fail by flexure, were, for instance, formed into corrugations, it would in this form support considerably more than in the form of a straight plate, for instead of being a mere line in section, with no depth, it would now possess a depth equal to the versed sine of the corrugations, or equal to the distance between

Fig. 5.

each convexity; and in this corrugated form we should attain the maximum resistance to pressure—viz., 16 tons, with our plates much thinner than when used straight. The depth would be still further increased if we folded our corrugated plate round upon itself, so as to complete a series of tubes, taking care to unite carefully the points of contact. There are numberless

Fig. 6.



familiar examples of stiffness obtained by such method of construction. An ordinary paper fan, and many household articles in tin, though constructed of thin and pliable material, are extremely strong and rigid from the depth acquired by the bending of the material. The domestic tea-board and dust-shovel are striking examples. It thus becomes a question, with a given section of material of a given thickness, how to construct the strongest form of pillar, or a series of pillars, to resist crushing, and how near we can with this form approach to the limit of 16 tons per square inch.

Since a flat plate, for the reasons explained, will bend sooner than a curved plate, it would be concluded, naturally, that a round tube, of moderate dimensions and of given thickness and section, would be a stronger form than the same plate in a rectangular form, in which the resistance to crippling must depend solely on the four angles; and since the rigidity afforded by the angles is extended throughout the four sides of a rectangular tube, in some manner proportionate to the distance from the angles, it would be concluded that a square tube would be stronger than a rectangular tube constructed with the same plate, inasmuch as the central portions of the longer sides of the rectangle will be less maintained in form on account of their greater distance from the angles; similarly increased strength might be expected from this form . These assumptions were all submitted to experiment, and confirmed. For this purpose a number of tubes or cells of wrought-iron were constructed, all 10 feet long; and either 4 or 8 inches square, or of rectangular form, about 4 by 8 inches; their ends were perfectly flat, and they were compressed, by the intervention of a lever, between two parallel discs of steel, with arrangements for maintaining the pressure perfectly vertical, the cells being supported laterally. The direct object was to ascertain the value of each particular form of cell, and to ascertain the resistance per square inch of section in each case. The lateral dimensions of these cells are so large, that with a length of 10 feet the pillars were not destroyed by a flexure, as in a long pillar, but by absolute buckling or crushing. The strongest possible form should therefore give about 16 tons per square inch of section.

Similar experiments were then made with circular cells, under precisely similar circumstances, for comparison. The cylinders varying from $1\frac{1}{2}$ inch to 6 inches in diameter; the diameter being so small in some cases, as compared with the length, some of these pillars failed by flexure, and followed the laws of long pillars, the resistance increasing nearly inversely as the square of the length; but where the diameter was 6 inches, the length being 10 feet, flexure could not take place, and the cells failed by buckling or crushing, as in all the rectangular pillars, and in such pillars the strength is independent of the length.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

To show how the failure in the rectangular and cylindrical tubes took place, the annexed drawings, as represented by Figs. 7, 8, 9, and 10, may be useful.

From the foregoing researches it will be observed, that in order to attain the maximum powers of resistance to compression in the use of iron plates in construction, that the square box with thin plates, next to the plate itself, is the weakest experimented upon; the next in the order of strength is the rectangular form with a division across the centre, as at *a*, but the best distribution of the material is in the cylindrical form. This latter cannot, however, be accomplished conveniently in shipbuilding, but the rectangular or cellular construction is applicable in all cases where resistance to compression, as well as tension, is required in the hull and upper decks of vessels.

Lastly—On the Distribution, Strength, and Value of Wrought-iron Plates and Frames, as applied to Ships and other Vessels.—In this department of inquiry, we have not only to consider the nature of the strains to which the sides and other parts of a vessel are subjected, but we have to determine the distribution of the material in the different parts of the vessel, so as to establish as nearly as possible perfect uniformity of strength. What we mean by uniformity is, that the resistances in any one part of the vessel should be proportioned to the strains on any other part, and that no waste of material should take place beyond what is necessary to maintain the balance of the opposing forces of strain and resistance. In our endeavour to determine the superior value of iron as a material of which vessels should be constructed, we have not entered into the question of distribution. This is, however, one of the most important elements of construction, and in order to approximate as closely as possible to uniformity of strength, we have to apply the material in such forms and positions as will effectually resist all the various strains to which the vessel is subjected.

It will be observed, that in the preceding investigation we have invariably viewed the question of vessels as they are now built, being subject to much severer strains than formerly, when built of wood. The present class of steamers are nearly double the length that they were formerly, as sailing-vessels; and the depths are much less in proportion, so as to render their powers of resistance to the action of the sea less than one-half that which would have been the case had the form of construction been upon the old principle. This being the case, a series of strains of double intensity are brought into existence, and these have to be provided against, if we are to have safe vessels on the new principle of construction. All these changes are elements of weakness, unless met by an equable distribution of the material, and it is on this principle that we have treated the new build of vessels as hollow girders. Let us, for example, take a first-rate ship of war, as built seventy years ago, such for instance as the Victory, and we have:—

	Feet.	in.
For the length between the perpendiculars	260	0
Breadth of beam	60	1
Depth	53	10

This, according to formula $W = \frac{adc}{l}$, would—if built of iron, and duly proportioned with sectional areas of 800 square inches, and if suspended on two points, stem and stern—sustain a load of the middle of 8785 tons, or 19,570 tons, if equally distributed.

Taking the same sectional area, and applying it to a vessel similar to the Warrior, and we have, with the same areas and the same constant 60, the decks being duly proportioned to the bottom,

	Feet.	in.
For the length	380	0
Breadth	58	4
Depth ... —	42	0

Hence $W = \frac{800 \times 42 \times 60}{380} = 5305$ tons as the breaking weight in the middle, or 10610 tons equally distributed, which is little more than half the strength of the former. From these facts it will be seen that we require an increased sectional area of 675 square inches in addition to balance the resisting forces of the two ships, which evidently shows that, increasing the length and diminishing the depth, the present build of vessels, when constructed of the same material, requires an increase of strength in the ratio of 1475 : 800 :: 1 : ·542. But this is not all, as we find from experiments on the effect produced on wrought-iron when subjected to alternate changes of load, that to build a durable vessel we should have to calculate the sections of the hull and upper deck, and to render it endurable under the varied strains to which it is subjected these should not, on the sectional area, exceed 5 tons per square inch.

A vessel thus constructed would, in our opinion, be perfectly safe under every condition when exposed to the action of the sea, but, if stranded upon a rock or shelving beach, with coal and cargo on board, she would be severely tried by the force of impact when continuously rising and falling, and subjected to the influence of a tempestuous sea. But even in this precarious position it is very questionable whether or not she would go to pieces. On the contrary, we are of opinion, if constructed with water-tight bulkheads, strong longitudinal keelsons, and double bottoms, that in nine cases out of ten she would hold together, and save the lives of all on board.

In the distribution of the material there is another consideration of great importance, and that is, that in all bodies in the form of beams, whether hollow or solid (they follow the same law as regards a transverse strain), the strains are always greatest in the middle, and progressively diminish to the points of support at either end. These facts are self-evident, and show in the case of an iron ship that the same thickness of plates is not required when working from the centre at midships to the stem and stern. In fact, they should taper and be reduced in thickness in the ratio of their distances from the centre till they reach the extremes at each end. Theoretically this is true, but in practice we have to consider how much the thickness can be reduced without danger to the structure, and in these we may here observe that the reduction should not exceed one-third between the centre and the two extremes. Or, in other words, if we assume the strakes or sheathing-plates of the bottom and round the bilge to the height of the interior floor, or one-fifth of the depth, to be ⅞ths of an inch thick, it then follows that their thickness may be safely and progressively reduced to ⅝ths thick towards the bow and stern. The same reduction to ⅝ths thick may be made from that point, one-fifth of the depth, to the neutral axis of transverse strains, or about half-way up the ship's side, when they should again increase to ⅞ths thick on the top strakes at the deck on each side, where they have to perform the office of stringers under the action of the two forces of tension and compression.

From these remarks it is obvious that a careful distribution of the material is a desideratum of considerable importance in ship-building; and although it may be necessary in some constructions to make deviations, it is nevertheless essential that the law of strains should be carefully observed, and weak parts effectively guarded against.

It will not be necessary in this communication to give drawings in illustration of these statements, as from other data the question may be rendered sufficiently explicit to enable the iron-ship builder to proportion the parts in the ratio of the strains, and to afford to the ship, as a whole, ample powers of resistance to the forces by which she may be assailed; care, however, being taken to provide for wear and tear, oxidation, and all those other influences which tend to weaken the ship.

I would have entered more on this question, but I have already exceeded the limits of an ordinary paper, and must reserve for some future occasion the further development of a subject of such deep interest in connection with naval construction. I may, however, state in conclusion, that the iron navy of this country is destined to take the place of the "Hearts of Oak," and become—as many now living may hope to see it—the dread of our enemies, the bulwark of commerce, and the harbinger of peace.

UPON THE SUPPLY OF WATER TO TOWNS.*

By Baldwin Latham, C.E.

Rainfall.—All supplies of water being derived from the rainfall, this is a subject that should receive careful attention, as the sufficiency and constancy of all works for the supply of water are dependent upon it. There may be, however, circumstances connected with each mode of procuring a supply that in some measure modify or alter the quantity, or affect the quality, of the rainfall of every district; yet there is no source, however remote it may appear from the rainfall, that is not directly or indirectly affected by the amount of that rainfall.

Rain is the result of the condensation of aqueous vapour, which is, at all temperatures, more or less suspended in the atmosphere. The quantity of aqueous vapour capable of being suspended in the atmosphere increases in a greater ratio than the temperature, and the phenomenon of rain occurs when the air, saturated with moisture, loses its temperature, and precipitates the excess it is no longer capable of containing, in an aeriform state, either in the form of dew, rain, hail, or snow. It is found that the first cause of rain is identical with those causes that produce the winds and currents in the atmosphere, viz., the changes of temperature, to some extent the electrical state of the atmosphere, and the magnetic state of the earth: consequently it very naturally follows that the winds have a very close connection with the rainfall. Thus, winds blowing from a warm climate over a great expanse of sea would be completely saturated with vapour, which, upon coming into a cooler climate, would be precipitated; on the other hand, a wind blowing from the frozen regions of the arctic ocean, and deriving its moisture from the ice and snow of those severe regions, would, when it arrived in a warmer climate, by lowering the temperature of the atmosphere of that climate, diminish its power to retain aqueous vapours; and if at the time it was overcharged with moisture, a fall of rain must ensue. The physical conditions of every locality have some effect upon the rainfall. Thus, from observation, it has been ascertained that the rainfall

* Paper read before the Society of Engineers.

is greater in mountainous districts than in level countries, which is probably owing to the currents of air saturated with vapour striking against the mountain sides, and losing temperature by contact or by reason of being compelled to ascend into higher and colder regions; there is, however, a limit to the effects produced by elevation, for there are regions too high to experience any heavy rainfall, as the rains of Switzerland, and among the Alpine regions, which show they are not greater than in the north of this country. The amount of rainfall is also considerably influenced by the position of the locality with respect to the currents in the atmosphere—for example, it is found that the prevailing winds in this country are westerly, and come to us from a warmer climate; after sweeping over the face of the great Atlantic ocean they are naturally saturated with moisture, and, striking the ridges and high lands on our westerly coast, discharge the greater portion of their burden there. Thus we find it is nothing uncommon in the counties of Cumberland, Westmoreland, and Lancashire, to have an annual depth of rainfall equal to 6 ft., while in Cambridgeshire, on the eastern side of the country, the annual rainfall seldom exceeds 22 in. The rainfall also varies with the seasons of the year, the rainfalls of this country being greater in winter than in summer, because the temperature of the atmosphere is decreasing in winter, and with it its capacity for retaining vapour, while in summer the opposite is the result. But it will also be found, as a rule, that heavier rains fall in summer than in winter, although there may be fewer showers; because in summer the atmosphere has greater powers for retaining moisture, so that when the causes that induce a fall of rain are brought into action, there is a larger amount of moisture to be precipitated. In Germany the rainfall of winter and summer are about equal; at St. Petersburg the rainfall of winter is but little more than one-third the rainfall of summer; while in Siberia the rainfall of winter is but one-fourth that of summer.

The rainfall of a district is ascertained by an instrument termed a rain gauge; and in fixing these gauges it should be borne in mind that the position and construction of the gauge has much to do with the value and accuracy of the results recorded; thus the fact has been well established that the amount of rain collected diminishes as the gauge is removed from the ground. Various reasons have been ascribed for this phenomenon. The most likely are that the cold rain-drops condense more vapour in their descent, and carry it down with them; or as has been supposed by Mr. Baxendale, of Manchester, that vapour that has lost its caloric of elasticity is capable of being suspended in the atmosphere in an invisible state, and is collected by the falling drops of rain. Rain gauges are of various forms, but those with float and graduated rods, which rise with the rainfall, are objectionable if the rod is exposed, as they are likely to exaggerate the rainfall of any district, because the rod collects rain driving in an angular direction.

The amount of rainfall recorded by the gauge cannot all be made available by the engineer in his works, as there are causes in active operation which render it impossible to collect the entire rainfall of any district. Therefore the engineer has to deal with resultants that arise during the constant and incessant circulation of waters, and before he can arrive at correct results he must carefully consider the subjects that affect the rainfall.

Circulation of Water.—The first source of rainfall is the ocean; by evaporation a portion of its waters are raised into the atmosphere to be again precipitated in the form of rain; of this a portion is again evaporated—another portion absorbed, while another portion may find its way back to the ocean—its original source. Thus it is that "the circulation of water is incessant—now in the ocean, now in the atmosphere, now in the tissue of plants or animals, now in the crust of the earth, now coursing its surface; and anon in the ocean again, to repeat the same circuit, and this without interruption while the present relations of the universe endure. In general this circulation is slow and gradual—so slow that the spherule of vapour now rising from the ocean may be years, or even ages, in returning to its native source. Disseminated in the tissues of plants, or locked up in the crystallization of minerals, its cycle seems interminably arrested, and yet we know that decay and degradation will some day or other bring about its liberation. On certain occasions, however, and in certain localities, its circulation is so rapid that you absolutely perceive the hazy vapour ascending from the sea, rolling landward in mist and cloud; coming in contact with cold mountain peaks, condensing into rain, and falling in torrents, to augment the runnels and runlets. From runnel to stream, from stream to river, the mass swells, and hurries downward and onward to the great receptacle whence the light and filmy vapour originally arose, there to resume the same career, and perform analagous functions." The water evaporated from the ocean may, for all practical purposes, be said to be perfectly pure; but in the course of its circulation it is constantly contracting impurities, and as frequently undergoing processes of purification. In this mighty circulation it performs important functions in re-arranging not only the tissues of plants and of animals, but in absolutely re-arranging the strata of this earth. All matter is animated in its presence, and it is, as it were, the life-blood of all creation. It is during the progress of this incessant circulation, as has been before observed, that the engineer has to deal with it, and in doing so he will find the available rainfall dependent upon certain conditions, such as the nature of the soil, the declivity of the district, and the rate of evaporation. If the nature of the surface receiving the rainfall is naturally, or has been made artificially impervious, there will not be any absorption, and evaporation will be the chief cause for any diminution of the quantity.

Evaporation.—It is extremely difficult to arrive at correct results as to the amount of evaporation taking place at any time either from land or water, as there are so many circumstances and conditions that may affect the subject and lead to errors: considerable caution must, therefore, be exercised in dealing with the results, and it is always better to be on the safe side, that the calculations of the engineer may not lead to a diminished supply of water. It is quite clear that the rate of evaporation from land is very much less than the rainfall, otherwise we should have no rivers or springs. But the rate of evaporation from water surfaces considerably exceeds that from land, and in some cases the rainfall. Dr. Dalton found from experiments made by himself, the mean daily quantity evaporated from a vessel of water freely exposed to wind and sun, to be in March, ·033 inch; in April, ·055 inch; in May, ·075 inch; in June, ·063 inch; in July, ·122 inch; and in the hottest weather of summer he never found the rate of evaporation to exceed ·200 inch per day. Experiments made by Mr. Luke Howard, at Plaistow, on the rate of evaporation from water surfaces, gave ·912 of the rainfall as the amount evaporated. In similar experiments made by M. Valles, at Dijon, the rate of evaporation was ·966 of the rainfall. A like experiment, made at the same time, but from a smaller vessel, gave a greater amount of evaporation, which in this instance exceeded the rainfall of the period. It is probable that the mean rate of evaporation in this country from water surfaces may equal 36 inches or 37 inches. In other countries the rate will increase considerably with the mean temperature.

The rate of evaporation from land surfaces must be, as has been before observed, much less than rainfall; but the precise rate it is difficult to arrive at, as the character of the soil, the state of its cultivation, and its general contour, affect the results very much. Thus, if the land is uncultivated and exposed, it would, by the action of the sun and wind, be dried very quickly; and when once the surface is dried, the rate of evaporation falls off; but in the cases where verdure covers the surface, whether it be in the nature of woods, or of grassy meadows, the vegetation protects the surface of the earth from the direct action of the sun and wind; yet in a more regular way evaporation is progressing, as the roots of trees and plants are abstracting the moisture from the soil, and retaining but a small portion, they give off the remainder into the atmosphere in the form of vapour. Experiments made by Bishop Watson on evaporation, on a bright and hot sunny day when there had been no rain for a month, gave the evaporation from grass as 0·35 inch in twelve hours. A similar experiment made after a thunderstorm gave 0·87 inch. From an experiment made by Mr. Lawes a plant of wheat was found to exhale 100,000 grains of water in 172 days, or the period of its growth; which would be at the rate of 2200 gallons of water evaporated from an acre of ground per diem, representing a rainfall of 36·5. It is probable, however, this is rather a high estimate.

The effect of evaporation, either from land or vegetation, is also a check upon itself, for as the circumstances arise to create a fierce rate of evaporation, it is in some measure counterbalanced by the cooling effect evaporation has upon the surface from which it takes place. The circumstances that favour evaporation are heat, a dry atmosphere, a low barometric pressure, and decreased weight of the atmosphere upon the evaporating surface; winds or currents of air also greatly promote evaporation, for they not only bring the air into closer contact with the water, but remove the particles of moisture as they are converted into vapour, and are continually bringing a fresh volume of air into action to receive its load of vapour. The rate of evaporation from most surfaces is in some measure compensated for by the deposition of dew, which is very rarely estimated with the rainfall.

Absorption.—The amount of rain capable of being absorbed by the surface upon which it falls depends in a great measure upon the temperature, the geological construction, and the physical outline of the district. In making calculations as to the amount absorbed, we must bear in mind that the area of the surface is the only constant quantity we have to deal with, as its condition and capability for absorbing water vary considerably with the seasons of the year. Under such varying conditions the amount of water absorbed, and capable afterwards of being used, when issuing from springs, or by sinking wells, is extremely capricious. The greater the quantity of water evaporated or retained by vegetation, the less will remain to be absorbed. Rain descending upon a dry and parched surface in the heat of summer, or during the occurrence of drying winds, will be nearly all evaporated, so that the rate and amount of absorption depends materially upon the absorbent properties of the soil. Thus in the sands of the red sandstone formation, the rainfall is absorbed as fast as it touches the surface, and the same may be said of the rain falling in many places on the chalk formation; while upon the clay soils, or impervious formation, the greatest part of the rain would generally be directly conveyed away by surface streams. The contour of a country in a measure affects the rate of absorption, as the rainfall on mountains or hilly districts has a greater tendency to gravitate rapidly to the rivers, while on table lands the rainfall lingers, and consequently such lands are favourable to absorption.

Experiments made by Dr. Dalton, extending over three years, on the new red sandstone formation, show that 25 per cent. of the whole rainfall percolated to a depth of 3 feet. Experiments made at Fernbridge, in Yorkshire, by Mr. Charnock, on the magnesian limestone formation, resulted in giving but 19·6 per cent. of rain percolating to a depth of 3 feet, and a like experiment made by Messrs. Dickenson and Evans, on the sandy gravelly loam which covers the chalk about Watford, gave as much as 30 per cent. of the rainfall percolating to a depth of 3 feet. In this experiment the average rainfall was found to be 26·33 inch per annum, and the average mean filtration 7·92 inch per annum. Of this quantity 7·34 inch were absorbed between October and March inclusive, which was at the rate 55½ per cent. on the rainfall of that period, while between April and September inclusive, only 5·8 inch of rainfall was absorbed, which was at the rate of 4½ per cent. of the rainfall of that period. From this latter experiment it appears that the largest amount of rainfall is absorbed during the months of November, December, and January, when, practically all may be said to have been absorbed; and that the least amount at any time absorbed was in the month of August, when, practically it was nothing. It has been calculated by Beardmore that of the rainfall absorbed in winter 60·7 per cent. is carried off directly at the time of the rainfall, leaving 39·3 per cent. to supply rivers and wells; and of this probably only 3¾ per cent. of the rainfall absorbed really goes to furnish a supply for wells, which in a measure will account for the failing of many ordinary wells in certain seasons of the year. This process of absorption plays a very important part in the economy of nature, as by it the rainfall is stored for the purposes of utilisation by both the vegetable and animal kingdoms. Were it not for this our rivers would only flow in times of rainfall, and at such times their impetuosity and floods would be so great as to prove a great drawback to their subservience for the purposes of man, while at other times their channels would be dry, which would probably be a greater disadvantage, as all vegetation would suffer materially, if it could survive the droughts we should experience; as it is, the water falling on the surface penetrates it to several depths, forming for itself subterraneous reservoirs, and it is from these reservoirs the water is emitted which keeps our rivers flowing and supplies water for vegetation, even in the time of the greatest drought.

Modes of obtaining Supplies of Water.—Having considered the two great causes that tend to diminish the amount of the rainfall that can be made available by the engineer in his works, it is now necessary to direct attention to the various expedients adopted for securing and furnishing supplies of water, and which may be classed under the following heads:—

1. By the interception of the rainfall before it reaches the ground, or before it has penetrated it; such, for example, as supplies taken from rain collected on the roofs of houses, or on the paved and impervious surface of our yards, courts, &c.
2. By the interception of the rainfall after it has reached the ground, but before it has run off by its natural course.
3. From rivers and streams.
4. From natural springs.
5. From wells.

Rainfall collected from Roofs, &c.—One of the simplest modes of securing a supply of water is by collecting and storing the rainfall that falls direct upon the roofs of our houses, or upon the paved surfaces of yards, &c. This mode is no doubt very ancient, and was probably one of the first expedients adopted for securing a supply wherever man had advanced to that state of civilisation as to require a house with an impervious covering for his shelter. The amount of surface available and suitable for receiving the rainfall is generally limited, so that the quantity of water capable of being stored is also limited; yet there are many places that depend upon this mode for procuring their principal supplies of water. A large portion of the supply of water for Jerusalem, Constantinople, and other ancient places was procured by storing the rain water in underground cisterns, some of which are in use to the present day. The city of Venice is an example of one of many places supplied principally by rain water; but it is found that in long, dry seasons, the inhabitants of such places as are dependent on this mode of procuring a supply of water are often put to great straits for a supply; and if we assume that 60 feet of roof or other impervious surface is available for each individual of the population with an annual rainfall of 30 inches, and that all of it is collected and stored, it would only give two and a half gallons per day as the quantity for each individual. Professor Leslie made a calculation, with respect to a lofty house in Paris, containing twenty-five persons, and he found that each person might procure a supply of little over one gallon per day. When those quantities are compared with the twenty to fifty gallons at present used by populations having a constant supply of water, it is easy to see the disavantages of depending entirely upon the rainfall collected on roofs and other surfaces connected with our dwellings as the sole mode of supply; at the same time it is advisable in many, if not in every house, to utilise the rainfall that can be secured on the site, as all such water, if collected and used, will have a good effect in diminishing the supplies it may be necessary to furnish by other and artificial means; moreover, such supplies of rain water are, in many districts, invaluable, where the water is naturally hard, and where soft water for the toilet and some other purposes is an absolute requirement.

The quality of rain water collected from the roofs of houses in cities or towns is invariably more or less varied in the degree of its purity; indeed it has been determined that pure water can nowhere be met with in nature, and the purer the water the more likely it is to contract impurities. The impurities contained in rain water are contracted partly by absorbing gases from the atmosphere in its descent, and partly from the impurities it meets with upon the surface that receives it, such as dust, insects, and soot, which accumulate during dry weather; and these impurities, although affecting the quality of the water for some purposes very slightly, yet, when they are allowed to accumulate in the cistern or storing reservoirs, undergo constant decomposition, and injure the quality of the water for many purposes. But inasmuch as many of these impurities, when first contracted, are of a mechanical character, they can be easily removed by a process of filtration, and as such system of purifying the rain water before it enters the cistern or tank is easily effected, it is very desirable that it should in all cases be done. In Venice this system has been adopted with great advantage and success, and Fig. 1 is a representation of the mode by which the water there is freed from its mechanical impurities, consisting of two wells concentrically placed. The inner well forms the pure water store, the outer receives the rainfall. In passing from the outer to the inner well the water has to filter through a stratum of sand. The best way to preserve the purity of rain water collected from the roofs of our dwellings is by preventing its exposure to light and heat; this can best be done in underground tanks, which should be well ventilated. It often happens that, for the sake of convenience, tanks or cisterns are constructed and placed in the upper portion of our dwelling, so as to furnish a supply without having to use mechanical means to raise it: but the purity and freshness of the water can never be compared with that stored in underground receptacles. The size of a tank for storing the rainfall should be sufficient to give a supply during the longest periods of drought, and consequently will depend upon the amount of the rainfall, the area of the roof or other surface, and the quantity of water required. Provision should be made to store not less at least than ninety days' supply, otherwise the supply may fail during long periods of drought, and when it is most needed. Mr. Bateman, C.E., has observed that droughts "vary in extreme length from, probably 120 days on the west coast of the backbone of England, to 240 on the east side."

Water Supplies taken from Collecting Areas.—The rain falling upon the surface of land, besides being partly evaporated and partly absorbed, has further a natural tendency to gravitate in the direction of the rivers and streams, which form the natural ducts or channels for carrying the rainfall back to the ocean, its original source. It is this portion, when on its way to the natural streams and water-courses, that is made use of in works of this character, and which are so constructed as to intercept the rainfall, either before it reaches its natural course, or, in some cases, after it has arrived in its natural channels, and to convey it to large impounding reservoirs, where it is stored in sufficient quantities for use as required.

Supplies taken from drainage, or collecting areas, or gathering grounds (as they are sometimes called), are by no means uncommon in this country, in conjunction with works for the supply of water to towns, and also for utilizing the rainfall for mechanical purposes. Works of this description are not of modern origin, but have been in use in past ages in many countries. A portion of the water supply of ancient Jerusalem, as mentioned by Dr. Whitty and others, was furnished in this manner, as a large drainage area contributed to supply the Pools of Solomon with water—in fact, these pools are reservoirs formed like those of many modern works, partly by throwing an embankment across a valley, and partly by excavation. The contents of the three pools, as given by Dr. Robinson's measurement, are as follows:—First pool has a capacity of 1,634,475 cubic feet; second, 2,536,414 cubic feet; third, 3,873,937 cubic feet; making a total capacity of upwards of 50 millions of gallons. These pools are arranged in the incline of a valley, the smallest being the highest, and the largest the lowest pool. As the second pool is only 160 ft. from the first, and the lowest but 248 ft. from the second, it is quite clear that a much larger reservoir might have been made by carrying up the embankment of the lowest reservoir to a greater height; but the probability is, that it was done as a measure of safety, for the additional depth of water would have added immensely to the risk of damage; and, indeed, the extreme care and caution which seems to have marked all the early hydraulic works is by no means a bad example to follow. The gigantic reservoirs of Egypt, for storing the waters of the Nile for utilisation, are ancient examples of works of this nature, and are of so stupendous a character, and of so remote a date, as to perplex and confound historians, many of whom have classed them with natural formation. But, as Ewbank observes, all ancient writers unite in asserting that Lakes Nigris and Mareotis are the work of men's hands. China also contains many traces of the early development and high state of mechanical and hydraulic science, and vast reservoirs, for containing water for the supply of canals, for agricultural and commercial purposes, are not at all uncommon there.

The care and skill of the Romans is shown, amongst other works, in those of this character for the supply of water to the cities and towns under their dominion; indeed, it is a remarkable fact that, in nearly every country and land subjugated by their arms, the remnants of their handiwork and skill are still to be seen. In many instances the benefits they conferred upon the past generations are still felt by the present generations occupying those countries. Works executed by them of the nature of collecting supplies from drainage areas are to be found in Spain, Egypt, and other places.

Like every other source of supply, there are many circumstances to be considered in constructing works for procuring water from drainage areas, the principal of which are—the rainfall, character of the soil, natural configuration of the district, and the state of its cultivation. Having determined upon the amount of rainfall, which in all calculations for new work should be the minimum, we must next consider the various circumstances that tend to diminish it. We have already treated of these under the heads of evaporation and absorption; but as each of these is more or less affected by the physical peculiarities of the district, we must carefully consider them. In every case where the surface soil is porous, a great portion of the rainfall will be absorbed; and in constructing works for collecting water from areas of this nature, it will be well to consider if, by suitable under-drainage, a larger portion of the rainfall cannot be collected, which, under other circumstances, would sink deep into the ground, beyond the reach of works of this character. Again, it may sometimes happen that a porous soil overlies an impervious bed, when a large portion of the rainfall could be secured by under-drainage, or the formation of deep intercepting drains. Again, in places where the surface is quite or nearly impermeable, the formation of under-drains will not add much to the quantity of water collected. It may then be taken by open channels, and the natural ones of the district will often suffice. Open channels are, however, objectionable, because, in most soils, the channel must be of such size as to limit the velocity of the current to a speed not exceeding half a mile per hour; otherwise the bed will be worn, and the water will be made turbid. This necessarily slow motion is attended by its evils, as it favours the deposition of silt washed from the surface of the drainage area, and is also favourable to the development of vegetable and animal life, and loss by evaporation. Open channels also form receptacles for vegetable matter, which the wind may carry in.

In considering the physical peculiarities of the district it must be borne in mind that, if the district is level and not intercepted with valleys, the expense of making impounding reservoirs, which in all works of this character are absolute requirements, will add immensely to the cost of such work; whereas, in districts traversed by valleys—often containing natural streams—impounding reservoirs can be more cheaply constructed by throwing an embankment across the ravine, and at once forming a natural reservoir. In computing the quantity of the supply likely to be furnished by drainage areas it is well not only to consider what may appear the natural areas or slopes receiving the rainfall, but also the geological areas, in considering which the engineer must pay particular attention to the dip and direction of the stroke of the strata, as it materially influences the flow of water. For instance, it often happens that the supply may be augmented by springs, when the dip of the strata is in the direction of the slopes of the drainage areas; while, on the other hand, the supply may be diminished by the facility with which the water may be carried away by an absorbent strata, having a dip in a direction opposed to the slope of the drainage area. The position, form, and dimensions of the drains for conveying the water to the reservoir will, in all cases, depend upon the contour of the district; but in cases where covered channels are used, the excavation, after receiving the conduit or pipes, is often filled up with broken stone, in order to facilitate the entrance of rain and drainage waters.

In laying out works of this character attention must be paid to the area of land enclosed by the catch-water and other drains; and, when practicable, the main conduit that will encircle the collecting area at the lowest point should be arranged at sufficient elevation to procure a fall, so as to enable the water to be distributed, without mechanical means being required to raise it to give sufficient pressure.

Quality of Water taken from Drainage Areas.—In laying out works for the collection of water from drainage areas it must be borne in mind that the nearer the actual rainfall water is collected the freer it will be from adventitious matter, and at the same time, in selecting drainage areas it must be observed that purity of water and fertility of soil are never to be expected together. Water taken from drainage areas where the substratum is peat, or from lands in a state of cultivation, is objectionable; as in the former case many vegetable organic impurities will be present; while that taken from land in a high state of cultivation will contract and contain many organic and inorganic impurities. The true quality of water contributed by drainage areas will always be found in the barren districts of the primary geological formation, and in the moorland on the sandstone rocks. Next to these the water taken from pastoral districts will probably rank in purity, and that from cultivated districts will be the worst. In cases where the water is collected quickly from the drainage areas, and before it has had time to penetrate deep into the earth, it is comparatively pure; excepting in those cases of highly cultivated and manured districts. Water taken from some drainage areas supplied by covered drains will not be as chemically pure as water taken direct from the surface without being allowed to penetrate the strata; as in such cases it may collect inorganic impurities from the soil.

Quantity of Water derived from Drainage Areas.—The quantity of water capable of being collected from a drainage area depends mainly upon the geological formation and physical outline of the district. If the district is of an impermeable geological character, having steep slopes, a very large portion of the rainfall can be collected; on the other hand, if the geological character of the district is porous, and its contour flat, as in some sandy and chalky districts, very little or no water could be depended upon from works of this character; and, as the geological character of a district approaches one or the other of these conditions, so will the percentage of the rainfall capable of being collected fluctuate. The engineer, in constructing works deriving supplies from drainage areas, must take into consideration the amount of water capable of being yielded by springs flowing in the areas, as it may occur that the rain falling on a porous part of the district may make its appearance again at another point in the form of a natural spring. As has been already mentioned, if the surface of the drainage area is porous, resting on impervious strata, a much larger quantity can be obtained by under-drainage, than if the water was taken from the surface only. The quantity of water capable of being taken by under-drainage, if the strata is uniform, will depend upon the depth of the drains. An experiment made by Mr. Milne, of Milne Garden, in Berwickshire, extending from June 1848, to April 1849, shows that under-drains 3 feet deep, laid 15 feet apart, gave nearly 36,000 gallons per acre; while drains laid 3½ feet deep, and 30 feet apart, gave at the rate of 47,000 gallons per acre, which was about one-tenth the rainfall of the district. It is clear from this experiment that a considerable portion of the rain descending on the surface, either ran off at the time of the rainfall, and consequently did not penetrate to the depth of the drains, or passed below them and out of reach of their action: in every porous soil a large portion of the rainfall could not be collected by drains placed a distance apart, as the water would penetrate deeper than them. From observations of some of the various works constructed for the supply of water from drainage areas, the amount of water taken and used varies from one-sixteenth to over two-thirds the rainfall of the district, as will be seen from the following examples of works in operation; but, as many of the works could probably supply a larger quantity, those given as the quantity is the amount absolutely used. There can be no doubt that if the surface of every drainage area was, or could be made, impervious, and sufficient slope be given to it to carry off the water quickly, a very large percentage of the rainfall might be used. But the great drawbacks to making the surface, that should receive the rainfall, impervious are—first, the expense; and, secondly, the restriction it would put on agricultural pursuits. The expense of making a surface impervious has been estimated by Mr. Hughes at £242 per acre, which price would exceed the value of the water that would be collected from it, so that if this system had to be put in operation at the present price of water, it would not pay. The sufficiency of the rainfall to furnish a supply of water may be derived from the fact that if two-thirds of the rainfall of England and Wales could be collected, it would furnish a supply to each individual of the population of a quantity exceeding 2500 gallons per day; but the rain falling on the sites of our cities and towns would not be sufficient for a supply according to the present rate of consumption. For example, the most crowded parts of London are peopled at the rate of one person to every 12¾ yards; now, taking this area with a rainfall of 24·8", if two-thirds of it could be collected it would furnish 2·63 gallons per head per day. In the city of London one person has 40½ yards area, which with the same rainfall and at the same rate would furnish 8·54 gallons per head per day. Although in a great place like London it would not be possible to utilise the quantity given, and the quality would not be the most desirous, yet for many purposes the quantity of rain falling upon the sites of our cities and towns, if utilised, would tend much to our advantage.

Examples of Waterworks supplied from Drainage Areas.—Ashton, in Lancashire, is supplied from a collecting area of 378 acres on the millstone grit formation. The rainfall of the district is 40 inches, and ·384 of the rainfall is stored.

Belfast, in Ireland, is supplied from a drainage area of 980 acres. The supply is taken by open channels, and stored in reservoirs capable of containing ninety days' supply, at the rate of 102,000 gallons per day. With a rainfall of 32 inches, ·522 of it is used.

Bolton, in Lancashire, is supplied from a drainage area of 1041 acres, situate on the millstone grit formation. The supply is taken by covered channels, consisting of pipes laid in trenches, covered with gravel, and the trench then sodded over. The water is stored in a reservoir capable of containing ninety days' supply, at the rate of 2,000,000 gallons per day. The rainfall of the district is 50 inches, and ·619 inches of it is used.

Dublin New Works are supplied from the river Vartry, which has a drainage area of 14,000 acres, and with a rainfall of 45 inches, and 20,000,000 gallons of water daily supplied: 500 of this will be used. The supply is stored in reservoirs capable of containing 120 days' supply.

Dukinfield, in Cheshire.—These works are constructed to be supplied partly from a drainage area of 383 acres, situated on the millstone grit formation, and partly by meter from the Manchester Waterworks. With a rainfall of 36 inches, it is found that about one half is stored and used. The water is taken from the land in both open and covered channels.

Glasgow is supplied with water from Lock Katrine, which has a drainage area of 43,000 acres, on the silurian formation, which supplies Glasgow with 23,000,000 gallons daily, besides 40,000,000 gallons daily as compensation to millowners. 130 days' supply is stored; and with a rainfall of 60 inches, ·402 of it is used.

Greenock is supplied from a drainage area of 5043 acres. With a rainfall of 60 inches, ·603 of it has been observed to run off into the reservoirs.

Huddersfield, in West Yorkshire, is supplied from a drainage area of about 1000 acres, situated on the millstone grit formation. The supply is taken by covered channels, and 120 days' supply is stored, which, besides supplying 500,000 gallons of water per day to the town, gives a large quantity of water as compensation to millowners. With a rainfall of 33 inches, ·537 of it is stored and used.

Liverpool is partly supplied from wells, but principally from a drainage area of 10,400 acres, contributing to Rivington Pike. A supply of 120 days is stored, and with a rainfall of 55·5 inches, ·436 of it is stored.

Macclesfield, in Cheshire, is supplied from a drainage area of 2000 acres, situated in the coal measures. The supply is taken by covered channels and stored in a reservoir capable of containing forty days' supply. With a rainfall of 40 inches, ·526 of it is used.

Manchester is supplied from a drainage area of 18,900 acres on the millstone grit formation, which furnishes a supply of 12,000,000 gallons per day, to a population of 550,000, and 55 cubic feet of water per second for twelve hours daily as compensation to millowners. With a rainfall of 37 inches, ·617 of it is actually used, while from Mr. Bateman's evidence it appears that nearly three-fourths of the rainfall can be made available.

Oldham, in Lancashire, is supplied from a drainage area of 2700 acres, situated in the coal measures, which furnished a daily supply to the town of 1,600,000 gallons, and 219 cubic feet of water per minute for twelve hours daily as a compensation to millowners. With a rainfall of 35 inches, ·415 of it is used, and six months' supply is stored.

Paisley is supplied from a drainage area of 790½ acres, situated on the coal measures. The supply is taken by open channels, and 200 days' consumption is stored. From a recent report of Mr. W. R. Copeland, the engineer, it appears that during the last year, with a rainfall of 56·33 inches, ·548 of it was used; but the amount capable of being supplied he takes at 84 per cent. of the rainfall, as he allows but 16 per cent. for loss by evaporation and absorption.

Preston, in Lancashire, is supplied from a drainage area of 3000 acres in Langridge Fells. The supply is taken both by open and covered channels, and 150 days' consumption is stored, with a rainfall of 43 inches, but ·232 of it is used.

Plymouth, in Devon, is supplied from a drainage area of 4000 acres, situated on the granite hills of Dartmoor. The supply is taken by open channels. With a rainfall of 44 inches, ·343 of it is used for town purposes.

Southampton is partly supplied from a drainage area of 120 acres, situated on the eocene formation. With a rainfall of 23 inches, one-third of it is collected.

St. Helen's Old Works are supplied from a drainage area of 280 acres, situated on the coal measures. The supply is taken by both open and covered drains, and is stored in a reservoir capable of holding 125 days' supply. With a rainfall of 30 inches, ·122 of it is stored and used.

Wigan, in Lancashire, is supplied from a drainage area of 2200 acres, situated on the coal measures, which furnishes a supply of 600,000 gallons per day to the town, and 800,000 gallons per day as compensation to millowners. The supply is taken by open channels, and 180 days' consumption is stored. With a rainfall of 40 inches, ·26 of it is used.

Water Supply taken from Rivers and Streams.—The water taken from rivers and streams is supplied by drainage areas of large extent. The distinction to be drawn between works deriving supplies direct from drainage areas, and from rivers that receive their supplies from drainage areas, is this:—In the case of drainage areas all the water of a particular district is dealt with, while in the case of rivers a proportion only of the water of a much larger district is taken. When all, or a large percentage, of the water of a river or stream is required, such works may be classed with those taking supplies from drainage areas, and will require the storing reservoirs and appendages of that class of works, as is the case with the new Dublin waterworks. Generally the water of rivers consists of water falling upon the various geological strata, from some of which it flows off directly; while from others it flows after penetrating to various depths, and issuing in the form of springs; consequently, the quality of river water is subject to greater variation than that collected from a limited drainage area, and is, in fact, a sort of mean between the waters of many sources.

The flow from some rivers and streams is subject to great variation, as streams that take their rise in mountainous districts, or which run over impervious formations, are often subject to freshets, while at other times these channels may be nearly or quite dry. It is found that the more impermeable the district, the more rapidly the streams swell and the rainfall is run off; whilst in permeable districts the soil retains the water and parts with it more slowly. Hence rivers flowing through such districts are not subject to such extreme variation of floods or droughts as those flowing through strata of a more impermeable character. The quantity of water flowing off by rivers and streams varies with the season of the year, and the physical and geological nature of the district from which the water is derived or over which the river flows. The discharge of water from rivers is not always proportional to the water shed, but depends more especially upon the geological character of the district, the amount of the rainfall, and the season of the year. The proportion between drainage and rainfall varies in different localities. Experiments made in 1835 upon drainage areas in Eatonbrook and Jamieson Brook valleys, in the State of New York, by Mr. J. B. Jervis, show that ·449 of the total rainfall ran off by drainage. From tables compiled by Mr. Beardmore, the Thames at Staines carries away ·119 of the rainfall of a district lying on the chalk, greensand, Oxford clay, oolites, &c.

The Loddon carries away ·118 of the rainfall from a greensand district. The Nene, at Peterborough, draining a district of oolites, Oxford clay, and lias, carries away ·081 of the rainfall. The Wandle, below Carshalton, draining a chalk district, carries away ·414 of the rainfall. Mimran, at Paushauger, from the chalk, carries away ·435 of the rainfall. Plym, at Sheepston, from the granite, carries away ·335 of the rainfall. Gleucore Burn, flowing from Pentland Hills, carries away ·131 of the rainfall. The proportion of rain drained off by rivers is not so great as that which is intercepted and impounded in the reservoirs of some works constructed to take their supplies direct from drainage areas; the reason of which is that the water of rivers is exposed to circumstances favourable to the processes of absorption, evaporation, and animal and vegetable assimilation.

Although the proportional amount of rainfall conveyed away by a river is not so great as that which may be collected direct from a drainage area, nevertheless the enormous drainage areas of rivers render them extremely useful for taking supplies of water, and it is a fact that the majority of the old-established cities and towns of this and other countries have been situated originally upon rivers and streams of various capacities, probably with a view to secure a sufficiency of water for various purposes, as well as on account of their forming a highway or road to facilitate the transit of their commodities, or as a protection and defence from their enemies.

One great drawback to the use of water for the supply of towns is its want of limpidity at particular seasons of the year, which necessitates the use of special measures for its purification. This want of limpidity is owing to the currents of water wearing away the sides and bed of the channel, or conveying the detritus washed from the surface of the land from which it may flow. The mechanical matter thus conveyed by rivers may be divided into two varieties, viz., that which is suspended in the water, and that which it rolls over the bed of its channel by the mechanical force of the current. The amount of matter transported by a river, under the latter circumstances, depends upon the velocity of the water, the nature of the bottom of the channel, and the shape, character, and size of the particles moved. From experiments made by Bossut, Dubuet and others, the size of particles conveyed by rivers flowing at different velocities is as follows:—

Velocity per second.			Materials conveyed by stream.
3 inches	...	...	Fine potter's clay.
6 „	...	...	Fine sand.
8 „	...	...	Course sand—size of linseed.
12 „	...	...	Fine gravel.
24 „	...	...	Pebbles—1 inch diameter.
36 „	...	...	Angular stones—size of an egg.

The way in which the particles of sand are transported by a river are interesting, and the examination of a sandy bed of running water presents a section of a series of undulations or inclined planes. The upstream side of these planes is very gentle, while the downstream side is steep. The grains of sand moved along by the water are forced up the long slope, and when they arrive at the top of the plane, fall down the steep side on to the foot of the next long slope of the undulations below, and so they are conveyed along; thus, in some measure, the rate of abrasion of the bed of the channel is diminished by this action. The matter that is urged along the bed of a channel by the current only influences works for the supply of water in cases where an accumulation of such matter has a tendency to choke or diminish the sectional area of the artificial channels or pipes provided for conveying it, when proper provision must be made against it.

The quantity of matter held mechanically in suspension in the water, depends mainly upon the velocity and specific gravity of the matter suspended. In all cases it will be found that the lightest matters are held longest in suspension; and in studying the physical condition of rivers it will be observed that, whenever any circumstances occur that have a tendency to reduce the velocity, a certain amount of the heaviest matters held in suspension will be precipitated; consequently, in rivers unaffected by tides, the lightest matter will be carried the furthest; and if precipitated, will be deposited at the outfall. The following table gives the proportional quantities of matter suspended in some river waters:—

Name of authority.	Name of river.	Proportion by volume.	Proportion by weight.
T. Logan, C.E.	Irrawaddy—flood.	[illegible]	[illegible]
Do.	„ ordinary state.	[illegible]	[illegible]
Mr. Ellet.	Mississippi (mean)	1/3000	[illegible]
Mr. L. Horner.	Rhine—flood.	[illegible]	[illegible]
Do.	„ ordinary state.	[illegible]	[illegible]
Do.	„ mean.	[illegible]	[illegible]
Sir Geo. Staunton.	Yellow River, China.		1/200
——	Seine—flood.		[illegible]
B. Latham.	Ouse at Ely—flood.		[illegible]
Do.	„ minimum.		[illegible]
Do.	„ mean.		[illegible]

There are so many circumstances connected with the presence of the mechanical matters held in suspension, that no general rule can be laid down as to the amount that may be expected under certain conditions; yet there are some known circumstances, such as increase of velocity, that favour the acquisition and transportation of such matter. The corroding and abrading action of water is incessantly re-arranging the strata of the earth's crust, and geology teaches us that the same results that are now being produced by the flow of our rivers, in conveying the particles of various geological strata from elevated localities to the valleys or the mouths of our rivers, have been in active cooperation for countless ages.

(To be continued.)

THE COMPULSORY SALE OF LAND REQUIRED FOR PUBLIC UNDERTAKINGS IN ENGLAND.*

II.

The Method of settling the Compensation and obtaining Possession.

MANY years since, in dealing with so-called private Acts of Parliament, the legislature found by experience that a number of provisions regulating the financial and traffic arrangements, the execution of works and the purchase of the requisite land, were necessary, both for the protection of existing interests, and for putting the promoters in a position for properly carrying out the undertaking for which the act was obtained. Such provisions, therefore, it was customary to insert in every special act. In course of time it further appeared, that in the majority of cases these special provisions should be identical, and in order to secure a certain uniformity, a short time previous to the year 1845, a kind of model bill was prepared by some of the officers of the House, containing all the different clauses which would have to be introduced, and agents were desired to adapt the wording of their bills to this form, as far as practicable. Thus a great step was made in advance; but a private act containing compulsory powers, especially such as one for a railway or canal, with its traffic and financial clauses, was a very bulky affair, extending perhaps to one hundred pages of printed matter. This, besides the attendant expense, was a serious inconvenience, as a volume of print had to be waded through to ascertain in what respect one act differed from another, or from what was usual in parallel cases. In the year 1846, when six or seven hundred railway and other private bills were introduced, the difficulty of printing them all, with the various amendments and alterations in their passage through the House, would have been enormous, had they retained their excessive dimensions. Fortunately, however, in the year 1845, chiefly at the instance of Mr. Booth, the then counsel to the Speaker, several bills were introduced and passed, having for their object the consolidation, into general acts, of each group of clauses which had, until that time, been introduced into every separate act. The result is that an important railway or public improvement act is now only an affair of ten or a dozen pages, containing the preamble, the special enactments as to the constitution of the company, the extent and objects of the undertaking, and such clauses as under the circumstances may be necessary in the interest of all parties concerned.

By a clause referring to them in every special act, such of the general acts as apply are to be taken as forming a part of the special act; any clauses of the general act which it may not be intended to incorporate being expressly excepted.

One of the most important of the general acts referred to, and that with which we have now more particularly to do, is "The Lands Clauses Consolidation Act, 1845" (8 Vict. cap. 18), which was designed to consolidate all the provision usually inserted in Acts of Parliament relative to the acquisition of land required for undertakings of a public nature, and to the compensation to be made for the same." This act was amended, or rather extended, in 1860, so as to afford further facilities for giving compensation by way of rent charges, and to enable the Secretary of State for War to avail himself of the provisions in the purchase of land for the national defences; with this exception the act has not been amended since it passed, and all compulsory sales of land are now regulated by its provisions. Similar general acts were passed for Scotland and Ireland, which differ in some respects from those for England; to the last I propose to confine myself in the present paper.

Although, in a few instances, such as where the executive government, a corporation, or board of health, acquire compulsory powers for the construction of new streets, sewers, or other works for the public benefit, some of the clauses of the general act are occasionally excepted or varied, it is almost always applied in its entirety in the case of a special act, conferring powers for the convenience or profit of the promoters themselves. It will, therefore, be best for us to deal with the general act, as it is usually incorporated with a special act, noting only as we proceed such exceptions as sometimes occur in the ordinary practice of a surveyor.

The Lands Clauses Act not only gives the power to purchase, but enables parties under disability, such as corporations, tenants in tail or for life, married women, trustees, committees of lunatics, and others, to convey or release lands to the promoters, which they otherwise would not be able to do. Several important questions arise as to the circumstances under which a person is entitled to compensation, and when it can be claimed; these, however, we will reserve till we consider the principles which are to guide us in ascertaining the amount to be paid, and for the present will take it for granted that both parties are clear in their respective rights, and that the only point in dispute is the sum which the claimant ought to receive for the sale of his estate and interest.

So soon as their act has been obtained, the promoters have the power, on giving three days' notice, of entering on any of the lands for the purpose of surveying, setting out the works, or boring to ascertain the nature of the soil, &c., on paying all the owners for any damage that may be caused by these proceedings. The Parliamentary plans being generally on too small a scale, and got up in too great a hurry to be depended upon, the first step the promoters take is to make very accurate surveys, and determine the exact position and extent of the intended work, so that the precise quantity of land required may be ascertained. The book of reference, also, must be corrected, and all parties interested in the property found out, so that they may be served with the notice next described.

NOTICE TO TREAT.—Within the "limits of deviation," as laid down on the Parliamentary plans, the promoters are the sole judges of the quantity of land they require; it must, however, be taken *bonâ fide* for the purposes of the undertaking, and for no other purpose whatever. This being ascertained, the promoters are to give to all the parties enabled to sell, a notice (commonly called "the notice to treat and agree,") which must define exactly the quantity of land required, and state that the promoters are willing to treat for the purchase of the same, and for the compensation to be made for all damage by reason of the execution of the works, and demand from the owner the particulars of his interest, and of his claim for compensation. These notices must be served personally on the parties, or left at their last known place of abode, or, if they are absent from the United Kingdom, or cannot be found, must be left with the occupier; or if no occupier, then affixed to some conspicuous part of such land.

Until the notice to treat is served upon him, the owner is not bound in any way, but may deal with his land as he pleases, by leasing it or otherwise, notwithstanding the special act has been passed, and he has been previously served with the "Parliamentary" notice. Immediately, however, such a notice has been legally served, the position of buyer and seller is established, and a contract for purchase is assumed to have been entered into, the owner cannot vary his interest, neither can the promoters withdraw their notice, without consent. There seems to be an exception to this in the case of commissioners appointed to do certain things for the public benefit, on behalf of the executive Government.

The notice may be for the whole or for any part of the lands of an owner, which the promoters are empowered to purchase; and if, after giving one notice, more land be required, they may give others, but a notice may not be for anything in excess of their powers, and an assessment by a jury for the value of this excess would be invalid.

By sec. 92 it is provided that the promoters shall not require a person to sell or convey a part only of a house or other building or manufactory, if such party be willing and able to sell the whole thereof. This provision has been interpreted very liberally on behalf of the owner. The promoters may, however, on receiving from the owner a counter notice to take the whole, withdraw the original notice, and decline to take any part.

It has been held, with reference to this section, that "a house" comprises whatever would pass with the grant of a messuage, and would include the garden and all that is necessary to the enjoyment of the house, if within one ambit. A mansion and premises, standing on about 1½ acre, were surrounded by a wall; a railway company took a part of the garden and orchard, and divided one part from the other; the company were held bound to take the whole. A meadow had been held for many years under the same lease, with a house and garden on the opposite side of a public road, it was used by the plaintiff and his children as a cricket-ground, &c.; a company gave notice to take this meadow, it was held that they could not be required to take the house and garden also. One of the lords justices, however, dissented from this view. Warehouses on the opposite side of a

* Continued from vol. xxvii. p. 314.

public road were held to be part of a manufactory, in connection with which they were used. The Charing-cross Railway Company required a small corner of the garden of St. Thomas's Hospital; they were compelled to take the whole hospital and premises, together with several residences adjoining, occupied by the surgeons and officers of the hospital.

Purchase of Land.—The promoters and the owners may agree between themselves both as to the quantity of land to be taken, and the compensation to be paid for the same, except that, in the case of any party under a disability to sell, the price to be paid, if it is not settled by a jury or by arbitration, must not be less than shall be determined by two surveyors, one appointed by each party, or if they cannot agree by an umpire to be appointed by two justices* and each of the surveyors, if they agree, or the umpire must annex to their valuation a declaration in writing of the correctness thereof.

Disputed Compensation.—If for twenty-one days after service of the notice to treat, the owner fails to state the particulars of his claim or to treat or agree with the promoters in respect thereof, the amount is to be considered as disputed, and is to be settled in the manner provided by the act.

Mode of Settlement.—If no agreement be come to, and the amount claimed in any case does not exceed fifty pounds, or if the claimant has no greater interest than that of a tenant from year to year, the same is to be settled by two justices. If the compensation claimed or offered exceeds fifty pounds, the claimant may have it settled by arbitration, provided he give notice to this effect to the promoters before they have issued their warrant for a jury. If the claimant does not so signify his desire, or if, when the matter shall have been referred to arbitration, the arbitrators or their umpire shall have failed to make their award for three months, then the question is to be settled by the verdict of a jury. It has been held that the umpire has three months within which to make his award, from the time when the duty devolves on him.

Proceedings before the Justices.—When the question of compensation is to be settled by the justices, any justice may, on the application of either party, summon the other party to appear before two justices at a time and place to be mentioned in the summons; and such justices may, on the appearance of the parties, or even in their absence, on proof of service of the summons, hear and determine the question, and examine the parties and witnesses on oath, and may award the costs of the inquiry at their discretion.

Settlement by Arbitration.—In any case authorised or required to be settled by arbitration, both parties may concur in the appointment of a single arbitrator; but if they do not so agree, each party at the request of the other must, by writing under their hand, nominate an arbitrator, to whom the dispute is to be referred. The appointment is deemed a submission to arbitration; it must be delived to the arbitrator, and neither party can revoke such an appointment without the consent of the other.

If, for fourteen days after a request in writing has been served by one party on the other, the last-mentioned fail to appoint an arbitrator on their behalf, the party making the request having himself appointed an arbitrator before giving the notice, may appoint such arbitrator to act on behalf of both; and he may determine the matter in dispute as if he had been appointed sole arbitrator in the first place. The death of either party to the dispute does not operate as a revocation of the appointment of an arbitrator; but if an arbitrator dies or becomes incapable, the party appointing him may nominate another to act in his place, and having the same powers; if he fail to do so within seven days after notice by the other party, the remaining arbitrator may proceed and determine *ex parte*. If either of the arbitrators, where more than one is appointed, refuse or neglect to act for seven days, the other may proceed *ex parte*, and make an award. If when a single arbitrator is appointed he should die or become incapable before making his award, the matters referred to him are still to be settled by arbitration; but the proceedings must recommence *de novo*, as if no arbitrator had been appointed.

The arbitrators, where more than one is appointed, must, before entering on the matters referred to them, appoint, in writing, an umpire to decide all matters on which they may differ, or which shall be referred to him; and in case the umpire die or become incapable, the arbitrators must forthwith appoint another in his place. The umpire must not be chosen by chance or lot; but when it is agreed that two or more persons are fit, there may be a selection from these by lot.

If for seven days after the request of either of the parties to the dispute, the arbitrators refuse or neglect to appoint an umpire, the Board of Trade if a railway company be one party to the case, or two justices in any other case, must appoint one on the application of either party.

If the arbitrators fail to make their award within twenty-one days after the last of such arbitrators has been appointed, or within such extended time (if any) as shall have been appointed by them under their hands, the matters referred to them must be determined by the umpire.

The arbitrators or their umpire may call for any documents they may think necessary, in the power or possession of either party, and may examine the parties or their witnesses on oath, and may administer the oaths necessary for that purpose.

Before entering on the consideration of the matters referred to them, every arbitrator or umpire must make and subscribe a statutory declaration, in a form set forth in the act, that he will faithfully and honestly hear and determine the matters referred to him, and the declaration is to be attached to the award when made.

The costs of the arbitration, and incident thereto, are settled by the arbitrators, and are to be borne by the promoters, unless the same or a less sum is awarded than has been offered by the promoters, in which case each party bears their own costs, the costs of the arbitrators being borne in equal proportions. The arbitrators deliver their award to the promoters, who retain it, but are bound to produce it at all times to the other party, and to deliver a copy thereof forthwith on demand. The promoters can be compelled by *mandamus* to take up an award. The submission to arbitration may be made a rule of any of the superior courts, on application of either party. No award under the provisions of this act can be set aside for irregularity or error in matter of form.

An arbitrator can only give a compensation in money, and cannot direct approaches or communications; nor has he power to apportion rent where part only of leasehold premises is taken.

P.

(To be continued.)

* A police magistrate in the metropolitan district may, by himself, do any act within his jurisdiction which is authorised to be done by two justices of the peace.

THE NEW WET DOCK AT LEITH.

By George Robertson, C.E.

On looking back at a paper I read to the Royal Scottish Society of Arts in September 1861, entitled, 'A description of the Reclamation Embankment for the New Dry Dock at Leith,' I find stated that one of the reasons which induced me to give that description, was a belief in the great importance to the inhabitants of Leith of a step which reclaimed for useful purposes even 6 acres of the large tract of sands lying unemployed in front of a town which suffers from narrow streets and crowded dock accommodation. Although it required no great spirit of prophecy to foresee that such a state of matters could not much longer exist, I certainly did not anticipate that, before that time next year, the plans would be definitely settled for giving life, energy, and value to the east sands of Leith.

During the last few years, the great increase in the import of corn, as well as the general prosperity of the trade of the port, more especially as carried on by steamers arriving and sailing at fixed periods, have taxed to the utmost its dock accommodation. The increasing size and draught of vessels require also a greater length of quayage in deep water than the limited size of the Victoria dock affords. When such a state of things exists in any port, it becomes imperative for its guardians to provide for the future, if they do not wish to see their traffic decline. But at Leith, it is especially necessary to be in advance of the requirements of shipping, as the neighbouring harbour of Granton offers, at least, deep water, though hampered with the inconvenience of the rise and fall of tide to which the trade is exposed in an open harbour. This may not be seriously felt when the rise of tide does not exceed 8 or 9 feet, as at Glasgow and some other harbours; but at Leith, where it is 18 or 19 feet, the convenience offered to shipping very much depends on the extent of *wet dock* accommodation.

In April 1862, the Commissioners instructed Mr. Rendel and myself to a report jointly on the additional accommodation required, and a report and plan were accordingly prepared of what we considered the best course to be adopted, both with regard to the present available means, and the future probability of extension. This plan was approved of by the dock commission, who at once put themselves in the necessary communication, first with the Board of Trade, and then with the Public Works Loan Commission, for the purpose of obtaining a loan for carrying out the design. The loan commissioners followed their usual course of sending down an engineer, in this case Mr. Beardmore, to report to them on the proposed plan; and on receipt of his report, signified their willingness to grant a loan of £223,000, upon certain terms of interest and repayment.

The Lords of her Majesty's Treasury, who appoint five of the Leith Dock commissioners, have also signified their approval of the plan, remarking "that they were satisfied that every endeavour had been made by the commissioners to provide increased accommodation in the manner most convenient and advantageous to the commercial interests of the town of Leith."

During the last half century the dock accommodation of Leith has been reported on by many eminent engineers. Messrs. Rennie, Walker, Robert Stephenson, Leslie, &c., have all had their various views on the subject: but since the date of the last report (which was before the construction of the Victoria Dock, and the extension of the two piers into deep water), circumstances have considerably changed. The extension of the east and west piers into 9 feet of water at low water of spring tides, with a channel between them up to the Victoria dock gates, settles the question of how the future docks are to be approached. It makes it unnecessary now to consider whether they should enter from the east or from the west, which was an open question when there was no deep-water channel at all. No better approach could now be economically devised than the present harbour, the depth in which is easily kept up by the dredger, and which there will be no difficulty in deepening for the moderate amount required for the new dock—viz., an average of 18 inches throughout the whole channel.

The question as to whether the dock itself should be built on the east or on the west side of the harbour, was a more difficult one, and required much deliberation, as the whole system of docks has hitherto been on the west side, with the exception of the Prince of Wales dry dock, lately built. Upon examining into the chief reasons for this preference, when the old docks were built by Rennie in the early part of the century, it was found that their position was settled very much by the level of the "boulder clay," which is higher on the west than on the east side of the harbour. When Rennie reported in 1799 on the construction of wet docks at Leith, his attention was first directed to the east side. "A dock there," he says, "has the peculiar advantage of lying contiguous to the dwellings and warehouses of the principal merchants in Leith, and of course will not only save some expense in the carriage of goods to their warehouses, but enable them to bestow a little more of their time in inspecting the loading and discharging of their cargoes." He also mentioned its capability of extension to any degree, along with other advantages. The principal inducements which made him, notwithstanding, prefer the west side, appear to have been that he would save £24,000 on account of the clay on that side lying at a more favourable level for the foundations of his dock walls; and that the thickness of overlying sand on the east side made the construction of a sea-wall there more expensive and uncertain. He therefore recommended that the docks should be built on the west side of the water of Leith, and they were accordingly built there by him several years afterwards.

The Victoria dock was also built there about 1850. At the present time, however, the principal disadvantages of the east side no longer exist, while the advantages remain the same. The level of the "boulder clay," which in Rennie's time was too low for the foundations of the walls then required, now suits admirably, when it is necessary to have 8 feet more water on the dock cill. The construction of a water-tight embankment 1400 feet long upon the east sands, for the reclamation of the ground on which the dry dock has lately been built, proves that an outer sea-wall down to the clay is not necessary to turn the water; so that the two principal engineering objections to a dock on the east sands are now removed, leaving us free to turn to points in its favour; and indeed, rendering the position of the new docks very much a matter of which side is the most convenient to the merchants and the trade of the port. On this point, I think, there cannot be much doubt. The principal merchants' offices, the corn exchange, the banks, and most of the chief centres of business in Leith, lie on the east side of the harbour, and of course most conveniently near any docks there. Although the custom-house is itself on the west side, yet it is absolutely 150 yards nearer to the corner of the proposed new dock on the east sands, than it would be to any dock which could be conveniently built to the west of the Victoria dock. Indeed, the custom-house and dock commissioners' offices will be nearer to the new dock than they are to any point of the old west or Queen's dock. In point of convenience to merchants, therefore, there can be little doubt which side is best on the whole.

The North British railway lies most favourably for extension round the new dock, while communication is also kept up with the railways on the west, by the drawbridge over the harbour. The main street of Leith, Constitution-street, which is the finish of the great road from Edinburgh, will be continued right up to the entrance gates of the new dock, and will form an admirable approach to it. Were a dock to be placed on the west side of the harbour, seaward of the present docks, it would be dependent upon their approaches. Any stoppage in them, from excess of traffic, or the drawbridges being open, would interfere with the new dock traffic. It is very desirable that every dock should have its own proper and independent approaches; and as a general rule, it is advantageous to spread a system of docks along the front of a town, both for the sake of independent approaches, and to render valuable as large a frontage of the town as possible.

The trade of Leith, especially the timber trade, is one which requires great space and wide quays; and the east sands offer a wider area above the level of half tide, than could be gained on the west side by inclosing the shore down to low water. They are therefore more cheaply reclaimed, acre for acre.

There are other advantages which might be enumerated in favour of the east sands, but enough has now been said to show their value for dock purposes, and we may turn to the points in favour of the west side. The principal ones are, the proximity of the Caledonian railway, now in course of construction, and the existence of the present docks and warehouses on that side. The benefit of the Caledonian railway on the west is fully balanced by the North British on that side. The warehouses at present on the west side are not in excess of the requirements of the existing docks, and new ones would have to be erected in either case. The establishment would also have to be increased, even if the new dock were to be built adjacent to the old ones. A little, however, might be saved on that head; and that small saving is about the only tangible argument in favour of continuing to build on the present site. Centralisation has its advantages, but it is possible, as has been shown, to have docks so close together as to cramp their quayage, and block up their approaches.

In designing the works now contracted for and about to be commenced, it was deemed desirable to think of the future, and show how the dock accommodation may be extended by adding an additional dock to the east of the new one. One dock is, however, all that is at present being constructed.

About 36 acres of the sands are to be reclaimed by an embankment 3480 feet long, in a depth of water nowhere exceeding 13 feet. This bank is to be somewhat similar in character to the one inclosing the dry dock, and which in a former paper I have fully described. It is to consist of a massive wall of dry rubble, faced with pitching, and backed by a wall of clay puddle, and common filling or sand. The chief difference between the two banks is, that in the new one, the water-tight puddle wall is to be continued down to the boulder clay by a row of cast-iron sheet piling. The piles are each to be 2 feet broad, 1 inch thick, and an average length of 12 ft. 6 in.; tongued and grooved into each other so as to make a tolerably tight fit. The reclamation bank for the dry dock had timber sheeting piles 9 inches thick, which were somewhat troublesome to drive through the wet sand. The coping of the bank is to have a strong timber parapet fence erected upon it as the work proceeds, both to keep off the heavy spray of the sea in gales from the north-east, and to form a boundary fence for the dock property. At some future time, when the bank has settled to its bearings, this can be replaced by a masonry wall. Two iron sluice pipes, 3 feet in diameter, with proper shuttles, are to be laid through the bank, for the purpose of letting out the water which may be inclosed when it is shut, as well as the drainage of the saturated sands. After the completion of the dock, one of these pipes will be taken up, added to the inner end of the other, and carried through the north wall of the dock, for the purpose of filling it gradually from the sea, and testing the gates. Within the area so inclosed, it is intended to construct a wet dock of 10¾ acres, with wharves round it of 200 feet wide at the least. The total quayage will be 3040 feet long; the length of the dock being 1100 feet, and the breadth 450 feet.

The entrance lock is to be 350 feet long by 60 feet wide, with a depth of water on the cill of 26 ft. 5 in. at high water of spring tides. This is 8 feet deeper than the old dock cill, and 2 feet deeper than the cill of the Victoria dock. The advantage derived from these extra 2 feet is very great. On an average there are 168 tides every year in which the depth on the Victoria dock cill is less than 20 feet. On the new dock cill there will be only seven, or less than $\frac{1}{24}$th of the present number. On the Victoria dock cill there are only 102 tides in the year giving 23 feet and upwards, while the new dock cill will have 396 tides of 23 feet, or four times the present number. This depth will prevent any possibility of a vessel being neaped, while it will enable most of the steamers trading to Leith to enter or leave the new dock at any time between half-flood and half-ebb. The depth of water in the dock itself will be 28 ft. 5 in., 2 feet more than on the entrance cill, to allow of the lock gates being kept open for some time after high-water, without any risk of a vessel grounding in the dock.

The lock is not to open directly from the harbour, but from an entrance basin of about two acres; because the outer harbour is so narrow as not to admit of the operations of locking and unlocking being conducted in it, without serious inconvenience to the shipping resorting to or leaving other parts of the port. The lock gates are to be made of creosoted yellow pine, a timber obtainable in Leith of large scantling, with the exception of the heel and mitre posts, and three bottom beams, which are to be of greenheart. Each gate is to have a sluice in it for keeping the entrance and bottom of the lock free of mud. The beams are to be trussed by iron rods inserted between the timbers, in a somewhat similar manner to those in the Victoria dock. The machinery for opening and shutting the gates, as well as that for lifting the shuttles in the filling culverts of the lock, is so arranged that at any time hydraulic machinery can be applied to it, without intefering with the traffic through the lock. It is also so arranged that no crabs or winches will appear above the level of the quay.

The dock, lock, and basin occupy 13 acres of the 36 inclosed by the bank, leaving a total wharfage of 23 acres, with a frontage of 1800 feet towards the town. There will be a new road, 60 feet wide, outside the boundary walls of the dock, running from end to end, with communication approaches from the shore of Leith at the west end of Tower-street, and Constitution-street at the east end. Between this new road and the town there will be some four acres of valuable ground, suitable for building purposes, which are at present leased to merchants for the storage of timber at a nominal rent.

The contract for the bank, and the excavation, masonry, machinery, &c., for dock, lock, and basin, has been let to Mr. William Scott, of Kilmarnock, for £189,285; but the total cost of the dock, when complete, with the requisite cranes and sheds, is estimated at £224,500. The entire area of the property belonging to the commission, available for dock purposes, will be at once doubled by the construction of these new works, which will not only keep pace with the requirements of shipping, but will certainly tend to promote the further development and prosperity of the trade of Leith.

Reviews.

A Treatise on Smoky Chimneys; their Cure and Prevention. By Frederick Edwards, Jun. London: Hardwicke.

That honest carpenter, Adam Bede, lets fly at the architects of his day a shaft which seems carefully made, and somewhat sharp in the point. He says, "The most of 'em don't know where to set a chimney so as it shan't be quarrelling with a door." His experience of them was possibly limited, and not of the best; let us hope that the compensation which he had for his early troubles included a complete immunity from all complaints of customers on this particular score.

The chimney and its belongings constitute a delicate and some-[what com]plicated machine: below, it is affected by the positions and aspects of doors and windows, and above, by the heights of roofs and towers; it has, besides, to encounter the opposition of other chimneys in the same house, and may suffer from all these causes, in addition to any demerits that are its own. Probably, by far the greater number of chimneys act well, or in a manner that by habit has become tolerable to us; where they fail, the causes of failure are difficult to trace, and in constructing new chimneys, no great pains are taken to adopt preventives which may never be needed, and would very likely be ineffectual. Yet, to design a chimney without due regard to proper rules, to construct it in a careless manner, and to fit it with such a grate as chance may provide, are so many methods of inviting one of the greatest nuisances possible in a house. So, when any author professes to lay down rules for our guidance, he is likely to find willing hearers; but as the subject has already been handled very many times, we are entitled to demand that his rules shall be drawn not merely from theoretical notions, but from close and intelligent observation of chimneys, both good and bad.

Mr. Edwards meets this demand in both kinds; he brings practical knowledge to bear upon his subject, gives good scientific reasons for the failure of flues to act properly, and proposes remedies for particular cases of failure. He gives rules for the construction of new chimneys, as well as for the reformation of old offenders; and we must say that his rules are generally clear and reasonable, and his remedies such as give fair promise of success.

Apart from such causes as an insufficient supply of air and the disturbing action of other fires, the failure of a chimney may be due to defects in any one of three several parts—in the part immediately above the fire, in the flue itself, or in its termination upward, where the smoke must make its exit from the house; these parts should be in due proportion to each other, and to the room to which they belong. The lower part of a chimney is usually made much too large, leaving room for a large reserve of cold air, which mixes with the smoke, and cools it so as to cause a sluggish current in the flue, and if the fire is kept up so as to heat this body of air, and the flue is sufficiently large to carry it off, the draught from doors and windows becomes unpleasant. In late years the size of this part of the chimney has been much reduced; but workmen need to be carefully watched, as their habit is to follow the old and bad system in this particular. Flues, also, are frequently constructed of an excessive capacity: in ordinary cases, 9 in. by 9 in. is an ample size; through such a channel the warm air moves briskly, and there is a small deposit of soot. The chimney-top should be carried up boldly, so that it shall stand out clear of all currents of air caused by high roofs and towers. There are in this pamphlet some illustrations showing the right and the wrong course in this respect, and the question of proper means of exit for smoke is discussed, with special reference to recent inventions.

Coming to the practical treatment of an obstinately bad chimney, and supposing that it is not cracked so as to admit the cold air, nor yet stopped up with rubbish, there are fifteen probable causes for its failure, each of which, with its proper remedy, is here discussed. If our author does not tell us how to determine the true cause at once, it is to be understood that he does not profess to make the cure of a smoky chimney so simple a matter that the exercise of intelligent observation will become superfluous. The subject must be studied by the light of his treatise, an extract from which will show his arrangement of these causes and their remedies:—

First Division.

Chimneys that smoke in consequence of a descending current existing, or being produced in the chimney.

CAUSES.	REMEDIES.
Cause 1.—From a fireplace being too open.	To contract the size of the fire-place, or use a contracted grate.
Cause 2.—From the doors and windows of a room being fitted too closely.	To supply air by means of doors and windows, or by means of a special supply near to the fire.
Cause 3.—From fires being lighted in two or three adjoining rooms, which are inadequately supplied with the air required by the grates in use.	To contract the opening into the chimneys. To give an additional supply of air. To use grates that will not allow much air to ascend the chimneys.
Cause 4.—From a chimney being very short.	To use a contracted grate with a blower. To reduce the height of the fire-place and the size of the chimney. To lengthen the chimney. To reduce the opening into the chimney at bottom and at top.

Cause 5.—From a chimney being situated in an external wall, and not being sufficiently protected against the action of the external air.	To improve the construction of the chimney. To use a very contracted grate. To reduce the opening into the chimney at bottom and at top.
Cause 6.—From a chimney being exposed on two or three sides to the action of air; the exposed brickwork not being sufficiently thick.	To improve the construction of the chimney.
Cause 7.—From a low chimney being in connection with a room adjoining a house or building in which the air becomes rarefied.	To supply the house and room liberally with air. To fit tightly the door of communication, or to use double doors. To use a contracted grate. To heighten the chimney. To reduce the size of the chimney.
Cause 8.—From a down current in a fire-place bringing smoke from an adjoining chimney.	To supply the room properly with air. To use a carefully fitted regulator to the chimney.

Second Division.

Chimneys that smoke in consequence of a descent of wind.

CAUSES.	REMEDIES.
Cause 9.—From the top of a chimney being situated below a pitched roof.	To heighten the chimney that its top may be above the source of obstruction.
Cause 10.—From the top of a chimney being situated near to a tower, or a similar source of obstruction to the wind.	To heighten the chimney. To use a simple protection as Fig. 12.
Cause 11.—From a short chimney being enclosed on three or four sides by high contiguous chimneys.	To heighten the chimney. To put a simple protection at top. To use the most contracted grates, and supply air below in moderate abundance. To reduce the size of the chimney or the extremities.
Cause 12.—From rooms with short chimneys being situated between the main body of a building and a contiguous eminence.	To build the chimneys of the extreme height of the main building. To use the remedies indicated for cause 4.
Cause 13.—From chimneys of one house being lower than those of one adjoining.	To heighten the chimneys. To put a protecting roof, as Fig. 13 or 22.

Third Division.

Chimneys that smoke in consequence of their being too small.

CAUSES.	REMEDIES.
Cause 14.—From a chimney being too small for the firegrate used.	To use a grate that will allow a minimum quantity of air to ascend the chimney. To reconstruct the chimney. To use a stove.
Cause 15.—From two fireplaces being used to one chimney.	To use well-contracted grates, with carefully fitted regulators. To supply rooms sufficiently with air.

The part of this treatise which will most interest architects, is that on the building of new chimneys, for which we have these rules:—

Rule 1.—To use grates of a contracted form, fitted with proper regulators, and to avoid grates with hobs.

Rule 2.—To avoid fitting doors and windows so as to practically exclude fresh air from a room; or to give a special supply of air near to a fire, in sufficient quantity, for which particulars have already been given.

Rule 3.—To build chimney-stacks, in all cases, as high as the highest part of the roof, and to terminate them by chimney-pots, or by Mr. Billing's division-piece.

Rule 4.—To terminate a chimney-stack by a projecting roof, as Fig. 13 or 22, whenever a building is lower than an adjoining one, or whenever the chimney-stack of one house is lower than a contiguous one of a house adjoining.

Rule 5.—To build all chimneys that are exposed on one side, or more, of 9-inch brickwork.

Rule 7.—To build all short chimneys of smaller dimensions than usual. Nine inches by 4½ inches are sufficient for ordinary attic fireplaces and labourers' cottages.

Rule 7.—To construct the fireplace of a low chimney not exceeding 30 inches in height.

Rule 8.—In constructing an extra room with immediate communication from the main building; to build a good chimney, if possible, against the main building, and terminate it as by Rule 3.

Rule 9.—When it is impracticable to build a lofty chimney against the main building, to construct the chimney no larger than amply sufficient; to use a contracted grate, with a blower; to build the chimney as high as may be convenient; to construct a low fireplace; to give a special supply of air near to the fire; to place a protecting roof to the chimney; and if the air in the house or building is likely to be generally more rarefied than the air in the added portion, to fit tightly the door of communication, or construct a double door.

Seeing that chimneys for coal fires have now been built for over two hundred years, it is time that the nuisance of smoky chimneys should be conquered by experience: to those who suffer from, or would avoid them, this treatise will be a useful guide. The author has wisely remembered that "time is money," and having given his views clearly, and with commendable brevity, supplements his text with a sufficient number of plates illustrative of courses that should be followed, and of some that it will be well to avoid.

Examples of Building Construction, No. 74. Simpkin & Co.

The number just issued is eminently calculated to sustain the practical utility of this work; the subjects are quite equal to those we noticed in the last part approvingly. Plate 53, a spirelet belonging to Llandogo Church, Monmouthshire, by J. P. Seddon, and Plate 54, details of one of the galleries in St. George's Church, Campden-hill, designed by E. Bassett Keeling, with its supporting iron columns, are both deserving of investigation, as showing some points of novelty in design and construction.

WAREHOUSES, SOUTHWARK STREET, BOROUGH, LONDON.

(With an Engraving.)

These buildings, illustrated by the accompanying engraving, stand at the corner of the new street connecting Blackfriars with the Borough, recently made by the Metropolitan Board of Works. They were erected for the firm of Messrs. Wigan and Cosier, the extensive hop-merchants. The group consists of three warehouses, each six storeys high, a residence for the person in charge, and a large courtyard, entered from Southwark-street and Great Guilford-street. A considerable portion of the courtyard is covered with glass, carried by a wrought-iron roof 60 feet high, beneath which eight or ten waggons may load or unload in the most unfavourable weather. Each warehouse is of the full cubical contents allowed by the Metropolitan Buildings Act. Two of the warehouses communicate with each other, and they are separated by double corrugated-iron doors. The loopholes in the courtyard are similarly protected by sheet-iron doors; these are hung in cast-iron frames throughout. The chains to the flaps are carried by plates built into the wall, so that the jar which is given to the brickwork by wooden frames is avoided by this arrangement. All the window-frames are of cast-iron. The floors are carried on iron stancheons, and all the loophole cells on iron girders. The blow on the buffers of jibs is received on a spring plate of iron on the inside; all vibration of the brickwork has been avoided as much as possible. As Southwark-street will most probably become one of the principal metropolitan streets, the architect has endeavoured to render his building worthy of its position, and has avoided, in a great measure, the unsightliness which generally characterises buildings of this class, by a judicious display of red, black, and malm bricks, cut and moulded, introduced with the picked stocks which compose the facing. In the cornice and strings some ornamental tiles have been advantageously employed. The frontage shown in our elevation, which is drawn to the ⅛th of an inch scale, is 167 ft. 9 in., and that in Guilford-street, 108 ft. 6 in. Care has been taken in the construction of these warehouses, that notwithstanding the stowage of hops was mainly considered, they might be equally well suited to warehouse heavy goods, as sugar, corn, &c. The works have been most substantially carried out by Messrs. Myers and Sons, under the direction of the architect, Mr. R. P. Pope, of King's-road, Bedford-row; and the clerk of the works, Mr. Walter Scattergood.

A Chimney, about 100 feet high, comprising 90,000 bricks, and estimated to weigh over 200 tons, was recently moved a distance of 100 feet in Worcester, Massachusetts, without breaking a brick.

THE CONSTRUCTION OF THEATRES.

At the meeting of the Royal Institute of British Architects, on the 19th ult., a paper on the construction of theatres was read by Mr. A. Warington Taylor. After a few introductory remarks on the arrangement and construction of ancient theatres, Mr. Taylor remarked that the designing of a theatre was not so difficult as it might appear, or as it has generally been considered. It requires, he said, none of the higher faculties of the architect —viz., a poetical sentiment. A theatre is used only for a few hours every evening, and very few beyond the fireman, hall-porter, and housekeeper, live in it. In its interior arrangement it in no way appeals to our domestic wants or habits, neither is there any sense of home in it, as in a domestic dwelling, where the architect has scope for the exercise of his imagination, in adapting the arrangements as to creature comforts in a manner pleasing to the eye; whereas a theatre offers none of these. A theatre is purely a piece of practical arrangement, which the greater part of the world never see or care to understand, and they are arrangements which are only required at certain hours, with no ties on our feelings like the arrangements of a house.

Mr Taylor then referred to the arrangements of Continental theatres as contrasted with those in this country, where the audience was divided into two classes—viz., the opera audience, and the playhouse audience; a difference, however, which is fast passing away. The plans for providing convenient modes of exit and entrance was next dwelt upon. He considered it to be a chief point to have as few entrances, and as many exits, as possible. People, he said, do not come to a theatre very suddenly, but by degrees; but in case of any sudden alarm, by fire or otherwise, the means of quick escape should be abundantly provided; and he alluded to the broad, long gallery stairs at Covent Garden theatre as a good arrangement, serving a double purpose —viz., of stairs and waiting-hall. In the case of the exits, he said, whenever two passages meet, the passage should be double the size, in order to let the double crowd pass easily down. The passages and staircases should be direct, so as not to give the audience a chance of choosing by which way to descend. In the new opera-house at Paris, this arrangement he considered very defective. A proper "crush-room," he said, should be provided, and above all, the pit exit clear from that of the boxes; if pedestrians can be let out at the side of the theatre, and the front kept for carriages, so much the better. Proper cloak-rooms, with water conveniences, &c., are all necessary adjuncts. Mr. Taylor then spoke of the best form for the interior. No modern theatre, he said, was required to hold more than two thousand five hundred people; although, perhaps, inferior theatres might require accommodation for three thousand. No shape, he said, was so good as that of her Majesty's Theatre—viz., the half circle continued with straight sides, very slightly contracted, till near the stage; if for a small house, an adaptation of the balloon principle should be adhered to, to provide additional room.

The consideration of acoustics was next dwelt upon, and here again Mr. Taylor referred to the superiority of Her Majesty's Theatre as the very best theatre in the world for sound—where there are no projecting ornaments of any kind—the pit tier fits tight on to the floor; there is no walk underneath the lower tier at the back of the pit, as in smaller theatres, and where the ceiling is perfectly smooth and even, and in form is a slight dome, fitting on to the house like the top of a violin; in fact, he said, the theatre ought to be a sort of violin, with the people sitting inside it.

Mr. Taylor then proceeded to the consideration of the ventilation and lighting, referring to the latter, of which he adduced the instance of the new Theatre Lirique, at Paris, with its glass roof, where, he said, treble the average amount of gas was consumed. As regards the ventilation, with plenty of holes near the ceiling, and a high pitched roof with domes, were, he considered, the best. Mr. Taylor next alluded to the decorations of the interior, which he contended should be under the direction of a true artist, not as is too often the case, a paperhanger and decorator. All ornament in relief might be considered fatal to sound; in addition, everything in relief catches the dust, and soon makes the house look shabby, besides being liable to be knocked off by the cloths hung over the boxes at night. He then referred to mediæval coloured decoration, instancing in particular the roof of Knapton Church, Norfolk, the principle of which, he said, might be applied to the ornamentation of theatres. As to the exterior, he would prefer extreme simplicity and truthfulness of expression, both as regards design and the material to be adopted, to all the attempts at so-called grandeur so often exhibited.

Mr. Taylor finally entered into detail as to the stage arrangements, preferring the manual labour and practical experience of well-informed stage carpenters, to the complicated and costly systems of machinery of late introduced.

ALLITHWAITE CHURCH, NORTH LANCASHIRE.

(With an Engraving.)

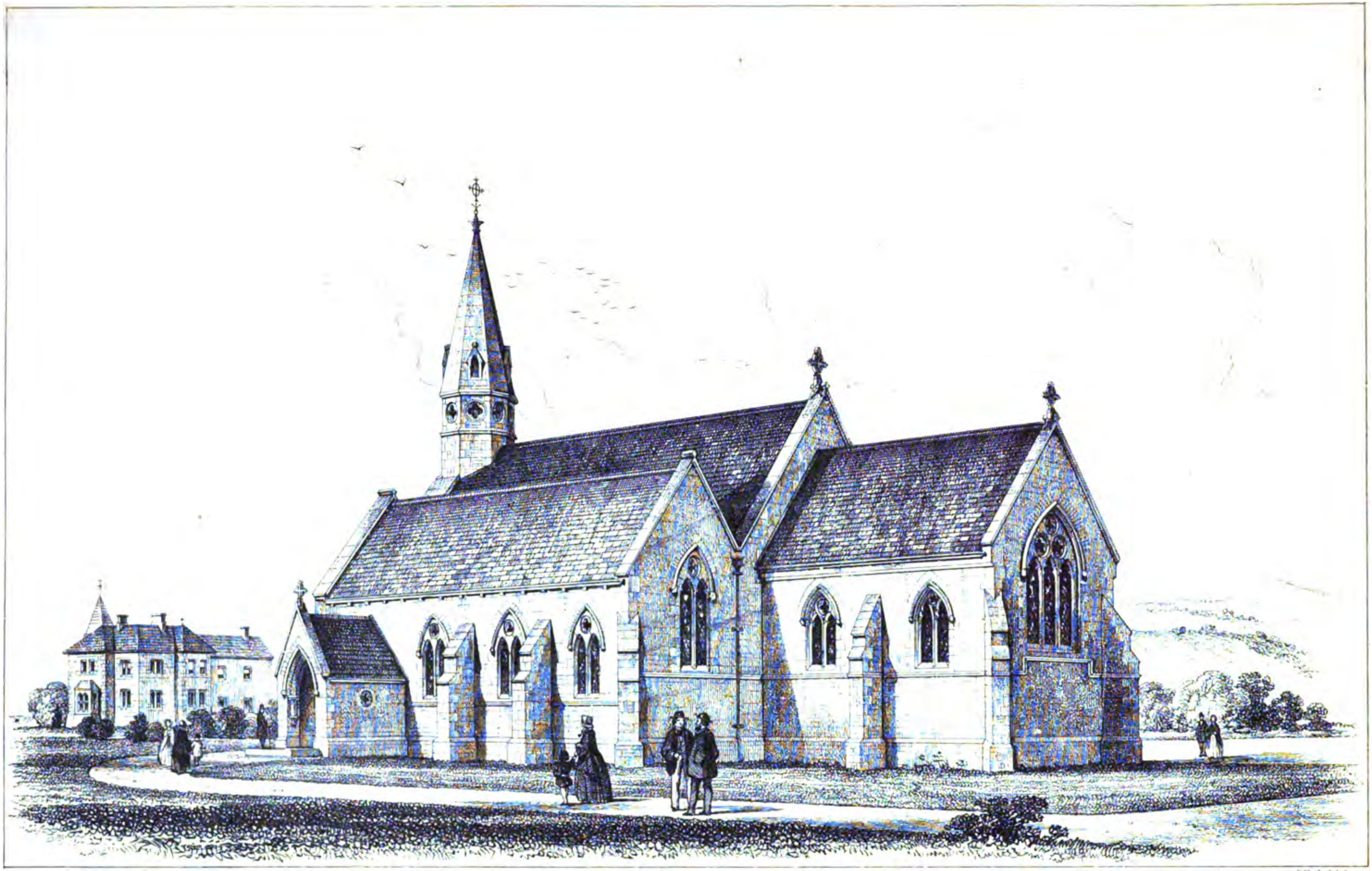
The accompanying plate is a perspective view of the church built out of the magnificent bequest of the late Miss Bowerbank (£12,000), to build and endow a church, parsonage-house, and schools, in this village, which is situated in the parish of Cartmel, North Lancashire. It is a conspicuous object to the traveller on the left-hand, as he approaches his journey to Ulverstone along the picturesque line of the Furness railway, where it stands on the centre of an admirable site between the Parsonage House and the Schools. Many difficulties had to be surmounted by the executors in carrying out the lady's requests. These have been overcome, and durability and economy have been studied by the architect, Mr. Paley, of Lancaster. The church gives ample accommodation for three hundred and fifty people. The structure is built of white freestone, from the Lancaster quarries, and the native limestone; and its cost has been about £2500, Mr. C. Baynes, of Lancaster, being the builder.

Notes of the Month.

The Magnesium Light.—A lamp for the purpose of burning the wire is said to have been invented by Mr. A. Grant, who is endeavouring to bring his design to practical perfection. Mr. Grant seeks to make magnesium cheaper still than the best stearine, and states that by burning a strip of zinc in conjunction with two strips of magnesium he is able to reduce the cost of the light by two-thirds. He even ventures to predict that magnesium will become as cheap as zinc, and that in the course of time it will be possible to illuminate a street a mile long, at the rate of a halfpenny per hour! It is not a small thing to be able to record that photography is no longer dependent upon the action of the sun. The value of magnesium as an illuminator for the purpose of "signalling," is too obvious to escape immediate recognition. The portable nature of the contrivance, and its perfect immunity from risk of explosion, together with some other evident advantages, render its vivid light all the more practically valuable. The Parisians, we are told, are going to make it figure on the stage, and have sent orders for some of Mr. Grant's lamps to illuminate their painted scenery.

Tunnel under the Liffey.—A tunnel is about to be constructed under the River Liffey, at Dublin.

Illumination of Street Names.—Several attempts have been made to render the titles of the streets of Paris as visible at night as in the day time, and at last apparently with success. The labels in the neighbourhood of the Hotel de Ville are now lighted up in the following manner:—The frame in which the letters are set is made in the form of a rectangular trough, the upper and lower portions being pierced with holes to allow of proper ventilation, and within this is a gas-pipe with a number of small jets according to the length of the tablet, and, consequently the number of transparent letters to be illuminated. The upper part of the box, or trough, opens to allow of lighting and repairs, and is closed by a counterpoise concealed in the stonework of the walls. We are not informed yet of the cost of this very useful arrangement. It was only in 1728 that the streets were marked with their names; previously to that time it was a mere matter of local knowledge and tradition, and it is little wonder, therefore, that the names of many streets and other places became so altered and vulgarised that it is now very difficult to trace their derivation. Of this, the street now called *Rue Git-le-Cœur* is a remarkable instance; there are two or three readings of the original meaning, but none of them satisfactory. The probability seems to be that the present title is the corruption of a proper name.



J.R. Jobbins.

ALLITHWAITE CHURCH.

E. G. PALEY, ARCH^T

Royal Academy.—At the recent examination of the Royal Academy, silver medals were awarded to Mr. Thomas Davidson, for his painting from the life; to Mr. Frederick George Oakes, for the best copy in oil colours; to Mr. Claude Andrews Calthrop, for the best drawing from the life; to Mr. Richard Lincoln Alldridge, for the best drawing from the antique; to Mr. James Griffiths, for the best model from the antique; to Mr. Sydney Williams Lee, for the best architectural drawing; to Mr. Horace Henry Canty, for the best perspective drawing; and to Mr. Richard Phené Spiers, the travelling studentship for one year, for architectural design.—On Friday evening, 16th December, at a general meeting of the Royal Academy, two associates were admitted to full honours to fill the places left vacant by Thomas Dyce and Sir Watson Gordon. The choice fell upon Mr. Thomas Faed and Mr. John Callcott Horsley. The vacancy by the death of David Roberts has not yet been filled up.—Mr. Solomon Hart, R.A., has been elected librarian of the Royal Academy, in the place of Mr. Pickersgill, R.A., resigned.

Slate in New South Wales.—Some pieces of slate have been brought down to Sydney, from a quarry on the property of the Ophir Mining Company, about 20 miles beyond Bathurst. The samples have been pronounced by competent judges of the material to be of a very good quality, and to be well adapted for flagging, making cisterns, and various other purposes. It is also stated that the edge of the slate would cut in two-thirds of the time that the Welsh slate takes to cut, by hand process, while with the chisel it cuts free and is not likely to flake up. The slate exists in great quantity at Ophir, and the discovery promises to be of considerable importance.

Public Works in Paris.—The Prefect of the Seine has just published his annual financial report, and from this and other official sources we learn the cost of the works carried on in Paris during the last twelve years. The amount expended on demolitions, reconstructions, and embellishments, that is to say, on extraordinary, as distinguished from the works of the city, is given as 900,666,627*fr.*, or, in round numbers, about three millions sterling on an average per annum. Of this total the city of Paris has supplied rather more than two-thirds, and the State less than a tenth; the balance being derived from a resale of land and other miscellaneous sources. The 900 and odd millions have been divided amongst various works in the following proportion:—Nearly 33 millions for charitable objects; religious edifices, upwards of 32 millions; municipal buildings and schools, more than 64 millions; the great market, nearly 12 millions; bridges and roads, nearly 50 millions; formation of new boulevards and streets, 590½ millions; extension of Paris to the fortifications, including the removal of the Octroi walls and gates, and construction of the new barriers, nearly 130 millions of francs. In 1859, Paris was lighted by 14,911 gas lamps, and the banlieue by 2812 gas and 750 oil, making a total of 18,939 lights, now increased to 30,395. The great system of drainage is approaching its conclusion; and in the month of May next, Paris will have its new river in the canal which is being constructed to bring the waters of the Dhuis to the capital; artesian wells have been sunk; large reservoirs for the supply of the city have been formed in the outskirts; half the theatres have been rebuilt; the parks and promenades have been planted and improved; many public squares have been planted and thrown open to the public; new roads and streets have been formed, and many old ones widened, ventilated, and otherwise improved. This is certainly a vast amount of work to have been done in a dozen years, even under the extraordinary circumstances of the case; and it is astonishing that even the immense sum given in the report in question should have been half sufficient for what has been performed. One of the most important, nay, the most important result attributed to the improved condition of the city is the reduction of the rate of mortality. In 1836, when the first quinquennial census was made in France upon the present system, the deaths were 2·78 per cent., or in the proportion of one in 36 inhabitants annually; in 1841 and 1846 the rate was nearly the same; but in 1856 it had fallen to one in 39, and is now stated at about 1 in 40. With respect to future works a commission has been appointed to draw up a general programme based on the following questions:—What buildings require re-building or enlargement to meet the necessities of the public service? What will be the expense of each? and what is the degree of urgency of each, and in what order should they be undertaken?

New Thermograph.—M. Marcy, of Paris, has invented a new registering thermometer. It has an adaptation of the air thermometer, and consists in a metal bulb attached to a tube of the same, which is but a fifth of a millimetre, or 0·0079 inch, in interior diameter; the receiver or indicator of temperature is a glass tube, bent into the form of a half circle, one extremity being closed and attached to the circumference of a metallic wheel, resting on knife edges, and counterpoised. A mercurial index is introduced into the glass tube, which it divides into two chambers, one closed and the other open; and the metallic tube of the thermometer is passed through the mercury, into the closed chamber of the glass tube. On the axis of the wheel above mentioned is an arm, carrying a tracing point, which marks the variations on a registering cylinder. When the bulk is heated the air passes into the closed portion of the glass tube, forces back the mercury, and of course disturbs the equilibrium of the apparatus to an extent marked by the tracing point on the cylinder. The metal air tube is furnished with a valve near the bulb, so that the interior may be placed in communication with the outer air, in order to set the apparatus at zero. This is one of the instruments furnished to the scientific expedition for Mexico.

Substitutes for Cranes and Hodmen in Paris.—Some of the contractors' rebuilding the demolished houses, and running up quickly new mansions, have hit upon an ingenious way of raising materials to the top of the scaffold. As the head of water at the Vilette is enough to command any of the houses in Paris, they have simply a pipe turned on from the main up to the top of the intended structure, and by that means can fill a bucket or large tub, which in descending draws up a plateau on which the materials are placed. The water, being turned into mortar, and otherwise made use of afterwards below, is not lost. Some of the materials are also hoisted by Lenoir's machine (by gas); there is one at work at the Rond Pont de Corcelles, close to the Avenue de Ternes. It seems to be, by timing a weight ascending a certain height, about 2½ horse-power. The absence of a boiler in these engines is a strong argument in favour of employing them where steady slight power is required.

Convention between France and Switzerland respecting Works of Art, &c.—A convention has been signed by the two governments by which the literary and artistic productions of each country will be protected in the other. The convention is for twelve years from the 1st of January 1866, and applies to printed matter, music, and works of art of all kinds.

Church Bells.—The new belfry of the church of St. Germain-l'Auxerrois will soon receive a set of chimes similar to those for which Strasburg, Dunkirk, Bruges, &c., are celebrated, but with the improvements suggested by the progress of modern mechanical art. M. Collin, who is entrusted with their execution, has rejected all the cumbersome old contrivances which exclude the possibility of playing several tunes except at an enormous cost. While the cylinder or barrel which works the chimes at Bruges, for instance, cost 60,000*fr.*, M. Collin's barrels will cost only 250*fr.* each, so that as every tune requires a barrel by itself, a great variety of tunes will be obtained at a very trifling cost. Instead of the enormous weights attached to the works under the old system he employs Lenoir's gas-machine as a motive power, whereby he forces air into a reservoir so as to produce a pressure of 2½ atmospheres. The air thus accumulated passes into a series of bellows, replacing the levers of the old system, and thus the artist who sets the chimes in motion finds an instrument as easy to play as a piano. The chimes will consist of forty bells, and will play two different tunes daily—one at two p.m., and the other at eight p.m.

Descriptive Labels in the Louvre.—An excellent method of furnishing the public with information respecting works of art is now being put in practice in the gallery of the Louvre. Tablets, on which are inscribed the subject of the adjacent pictures, together with the names of the artists, the dates of their births and deaths, and the title of the school to which they belong, have been placed, at intervals of about six yards, along a portion of the Italian department of the gallery. These tablets are conspicuous enough to attract attention, and cannot fail to make many persons, unversed in matters of art, think a little, at least, about the pictures, which otherwise they might, and very often do, regard as mere pretty curiosities, and this will be a real step towards art education.

Warming of Railway Carriages.—It is reported that experiments in warming carriages by steam have been made on the Royal Eastern line of Prussia, between Bromberg and Thorn, and with complete success. Previously the carriages reserved for ladies were warmed by means of hot sand or stones, but both were found insufficient or objectionable. In the new arrangement, a special boiler is placed in a luggage van, and the steam is conveyed, by means of junction pipes, into wooden cylinders, placed in all the carriages. Each compartment is provided with a small lever, which enables the travellers to regulate the temperature according to their feelings. During the experiments in question the heat was maintained at 22° Reaumer.

The Atlantic Cable.—The entire length of the Atlantic telegraph will be 2300 miles. There are seven copper wires to form the conductor, so that there are 16,000 miles of copper wire. Every portion of this wire is subjected to electrical tests to ascertain its quality for conduction before it is allowed to be worked up. The next stage is to coat these with eight successive coats of the insulating material, equal to 18,400 miles. This core is next covered with jute wound round it from ten strands, making 23,000 miles of jute yarn. Then comes the outer coating formed of the ten covered iron wires. The iron wire itself is 23,000 miles in length, and each wire is covered separately with five strands of tarred hemp, 135,000 miles of the latter being required, making together an aggregate length of material employed of 215,000 miles.

Electro-Magnetic Locomotive.—At a meeting of the Scientific Society of the Department of the Seine-et-Oise, held at Versailles a few days since, a model of an electro-magnetic locomotive was exhibited and explained by its inventors, MM. Bellet and De Rouvre. This new engine is intended to run on rails, and the arrangement of its parts is somewhat curious. The driving power is given to a single pair of wheels, situated at the rear of the engine, as in the Crampton engines. A number of magnets are arranged radially on these wheels, their poles towards the circumference; the voltaic current is conducted from the centre of each wheel to all the magnets in succession, and these latter act directly on the iron rail itself. The inventors claim for their engine the great advantage of excessive simplicity, and, moreover, that as the magnets act directly on the rails, there is a constant amount of adherence, which does away with the necessity of weight to ensure safety, even with the highest speed possible. The inventors seem to have especially in view the postal and telegraphic service. They say:—"This machine may be employed to carry letters and parcels in the interior of towns at the rate of twelve or fourteen miles an hour, on subterranean railroads, connecting the principal post-offices; and as the locomotives for such service would be very small, the works would be comparatively inexpensive. Larger machines might run on the existing railroads, and convey despatches at the rate of a hundred and twenty miles an hour." The machine is ingenious, and doubtless works well in a model; but it remains to be seen whether it would be practical on a larger scale.

Gas in Egypt.—On the evening of the 23rd September, the city of Alexandria was lighted for the first time by gas, the works having been erected by a French company. The lamplighter is nightly followed in his rounds by a crowd of wondering Arabs, who insist that the marvellous blaze following the touch of his torch must be provoked by the will of a *genie*, or "djinn," as Mr. Lane would have us spell the familiar word of the Arabian nights. This improvement causes a great change in the habits of the place. Heretofore a municipal regulation had required everybody going abroad after nightfall to carry his own lantern, but this is no longer necessary.

Paris International Exhibition, 1867.—It is reported in Paris that the idea of erecting a huge building over the Seine is given up—which will astonish few persons—and that the building for the next Great Exhibition will be a Crystal Palace, erected in a new boulevard, extending from the Arc de Triomphe, at the top of the Champs Elysées, to the river. The building now projected is to be large enough to give every country as much space as it may desire. It is to occupy the central portion of the boulevard, only leaving space for a carriage-way and four pedestrians, and on the other for a railway, or probably an American tramway. It is proposed to erect a steam lifting pump on the bank of the river, to supply the requisite quantity of water for all purposes.

Another Railway in New Zealand.—An offer has been submitted to Government to make as soon as the state of the country would allow, a railroad to Wanganui. It is to be a single line, capable of carrying an engine of not less than 15 tons, but the offer does not include stations or rolling stock, the line to be given up piece by piece as completed. The payment asked for is land, at the rate of an acre and a half for every pound sterling expended by them in making the railroad, up to £4000 per mile, that is to say, that each mile of railway will cost 6000 acres of land, but cannot cost more. It is proposed that the contractors should not take the whole of the land adjacent to the railway, but take it in blocks alternately with the Government.

Submarine and other Foundations.—An invention of Captain Thomas Bridge Heathorn, R.A., of 14, St. James's Square, London, has for its object improvements in the construction of submarine and other foundations in deep water, under the circumstances of a level, shelving, or sloping bottom of a varying density, possibly covered with mud, sand, or shingle, to a great depth. The method of constructing the foundations for such structures upon a level bottom is as follows:—The caisson, which is of annular construction, with a triangular section, is made of sheet iron; the bottom portion is floated out to sea, exactly over the spot upon which the building is to be erected, and there anchored; concrete is then placed in the caisson, so as to cause it to sink equally, and, as soon as it is sufficiently deep in the water, an additional height of the caisson is fixed, and more concrete placed therein to sink it deeper. This operation continues until a firm foundation is obtained by the weight of the caisson with its interior filling of concrete causing it to sink through the mud or other soft ground to the hard ground beneath; the interior is then filled up with stone or concrete, upon which, and the concrete in the caisson, the superstructure is erected. For shelving or sloping bottoms, the caisson will bear only upon the highest side of same; and to preserve the perpendicular of the said caisson, immediately it touches the hard ground, stones are placed in the interior of the caisson, which will naturally settle themselves in such position as to form a wall underneath that portion of the caisson which does not touch the hard ground, thereby forming a foundation upon which the caisson may rest. The mode of obtaining foundations in deep water will also apply to obtaining same in soft or peaty ground on land, and in some cases the interior filling of stones will be omitted, and the caisson allowed to sink until it is prevented from further movement by the internal apertures closing, as the building up of the inner side terminates in a conical apex.

Church Decoration in Paris.—A sum equal to £11,584 has been devoted to the decorations of the new church of St. Augustin. The interior of the cupola is to be illuminated with large figures, sixteen in number, of prophets, saints, and fathers of the church, surrounded by cherubim, on a blue ground, studded with golden stars; in the pendentives are to be painted the four evangelists, accompanied by angels; the vaultings of the side chapels are to be painted with six subjects from the lives of St. John, St. Peter, and St. Paul; these, with one or two minor commissions, amount to nearly £2,880. The stained glass, and three medallions beneath the porch, in distemper colours, enamelled, amount to £2760. The sculpture includes a bas-relief, for the porch, of Christ and the twelve apostles; a marble statue of the Virgin Mary; more than twenty statues of the evangelists and saints, for the decoration of the façade of the building, with minor works in stone, and bronze figures for the doors—together, £5944.

Sun Motor.—The other day a means of cooking by the aid of the sun was proposed by M. Babinet, of the French Institute; another professor, M. Mouchof, suggests an application of the sun as a motive power. If, he says, a bell or cylindrical reservoir, of thin silver, blackened within, be filled half with water, and half with air, and let the sun's rays fall upon it through two bell glasses placed over it, the air will expand and press upon the water. If a tube with a stop-cock be inserted near the lower part of the silver reservoir and curved upwards into a vertical position, the water upon the opening of the cock will leap to the height of ten metres, and the fountain will be maintained as long as there is any water in the receiver, but the moment any body intervenes between the sun and the receiver, of course the action diminishes, and soon ceases entirely. M. Babinet thinks that such an application of the sun's power might be of advantage in Egypt, where, as he says, "the sun costs nothing."

THE MANAGEMENT OF TOWNS.

II.—*The City of London.*

THE portion of the metropolis, covering about a square mile f surface, that has formed the nucleus round which the other parts have gathered, and which is known as "the City of London and the liberties thereof," is in respect of its sanitary arrangements, as in most other matters, under special local control. In this particular the powers possessed by the governing body are older and, even now, more ample than those in the hands of other local authorities. It is, of course, urban from centre to margin, and is surrounded by districts of a similar kind, with the difference that in the City the land is more valuable, the buildings more massive and costly, and the traffic greatly in excess of that on any similar area. The growing demand for warehouse and office accommodation has in many parts operated to clear away the dwellings and diminish the numbers of the residents, but in other portions the population is dense, owing to the necessity which drives numbers of the poorer classes to reside near particular spots, and as it is now nearly the same in amount as it was fifty years since, they have become packed together in a way that produces incalculable mischief to morals and to health. It is an exceptional kind of population, standing by the last census at 113,387, but receiving daily a very large accession of persons drawn thither chiefly by business, who make a large demand upon the machinery of local management.

Over a large portion of the area the footways and carriageways are inconveniently crowded during sixteen out of the twenty-four hours, and at many points stoppages of the traffic are constant, although it is regulated by a staff of police officers specially detailed for that service. Except in one peculiar locality the whole of the public ways have for many years been paved; all the courts and alleys that have no cartway being laid with flagstone, and all parts are daily swept. The supply of gas and water is in the hands of powerful companies. Burials have been discontinued in the City for some years, and a cemetery has been provided at a distance of seven miles from its eastern boundary. With the exception of a narrow strip along the margin of the Thames and running up the valley of the Fleet, the ground is high, and lies well for drainage purposes. At present the whole of the sewage is discharged into the river, and the City has its full share of the nuisance which it joins with the rest of the metropolis to create.

There is not throughout the City any space specially set apart and kept for a public garden or pleasure ground, though, as we may take occasion to show, there would be no great difficulty even with property at its present value, in making a fair provision of this necessary adjunct to a town. Of open spaces, there are the old Smithfield-market, now undergoing transformation; Finsbury-circus, St. Paul's-churchyard, and certain other places, closed to the public by fences of open construction; a few squares more or less confined, and some irregular spaces occurring at the intersections of streets, as at the Royal Exchange, which provide a certain amount of ventilation, while some of them adorn the City. But along the southern side, which is its longest boundary, the Thames—three hundred yards in width, and soon to be freed from the filth that now drains into it—runs from the open space of the Temple-gardens to that of Tower-hill, both of which are just without the city boundary. These, taken together, give an amount of breathing space which is not inconsiderable, and would, if fully utilised, greatly assist in preserving the public health. But, lying in the centre of a large district which is of an exceedingly unfavourable character, the health of the City is terribly dependent upon the vigilance and efficiency of other public bodies, over which it has no control. The following statistics show the condition of the City in respect of several important matters:—Area, 621 acres; length of Public Way, 51 miles; area of ditto, 160 acres; number of Streets and Places, about 1000; number of Houses, about 16,300.

The Commissioners of Sewers of the City of London are appointed and perform their functions by virtue of powers given by the City of London Sewers Acts of 1848 and 1851 (which replaced older Acts of similar character), wherein the Mayor, Aldermen, and Commons are directed to nominate and appoint such and so many persons as they shall think proper to be the commissioners for carrying these Acts into execution. The Lord Mayor, the Recorder, and the Common Sergeant are to be three of the commissioners; and it is the practice to appoint annually, in addition to these, the aldermen, the deputies, and one common councilman from each ward, making together about eighty-three members.

Though comprising the leading members of the Corporation, the Sewers Commissioners exist and act as a distinct body; holding property, having their own offices at Guildhall, and employing their own officers and servants. In them is vested the property of the pavements within the City, and the sewers, except such main sewers as are, by 18 & 19 Vict., c. 120, vested in the Metropolitan Board of Works. They are the body which within the City perform such duties as belong to a local board of health, and other duties of an allied kind, that are cast upon them by Acts relating specially to the metropolis. They are empowered to raise money for these purposes by a sewers rate of fourpence in the pound, in one year, and a consolidated rate of one shilling and sixpence in the pound; the last being for the purpose of making and repairing, paving, lighting, cleansing and watering the streets, and effecting public improvements; also for works to sewers, and for salaries, and other expenses incurred in exercising the powers granted to the commission. For certain purposes the commission acts in the same manner as one of the district boards under the Metropolis Local Management Act, and it is practically represented upon the Metropolitan Board of Works, though the three members sent by the City to that board are appointed by the Mayor, Aldermen, and Commons.

Of the functions performed by the City Sewers' Commission, our business lies only with those that are in the department of the engineer and surveyor, or are of a nature to influence his proceedings (as are some of the duties of the medical officer); these have been greatly augmented during the last few years, in which the importance of works for improving the sanitary condition of populous places has been more fully recognised. In dealing with these matters, it would not be useful to extend our inquiries to any remote period; except in so far as the long continuance of a particular practice may afford better means for judging of its effects. For several years before their present extended powers were obtained, the commission had been reconstructing the system of sewerage within the city; sewers of the modern improved section were in general use, and were inspected and cleared of deposit. All streets, courts, and alleys were, as has been said, paved throughout; and since 1845 they had all been swept once in every day. Since the passing of the Act of 1848, however, every part of the system has been from time to time reviewed and reported upon, as well as all new duties that have by various Acts been cast upon the commission. The reports of their engineer and surveyor, Wm. Haywood, Esq., M. Inst. C. E., F.R.I.B.A., who has held that appointment since 1846, are printed, and, together with the reports of the medical officer and other papers bearing upon the proceedings of the commission, are deposited in the library at Guildhall. They include reports upon sewers with their liquid and gaseous contents, pavements, traffic, gas and water supply, cemeteries, sanitary works, street improvements, cleansing and watering, projections from houses, and all other matters within the jurisdiction of the commission. One great object that has been kept in view is the constant and thorough inspection of the city, both in respect of the public ways, and of nuisances that are detrimental to comfort and health. It will be convenient if we give an outline of this system as it now exists, before alluding in detail to the various works and matters for which the engineer is responsible, and which are subject to such inspection.

Inspection of Pavements, &c.—For this purpose the city is now divided into four districts, to each of which an inspector is appointed, who is required to possess sufficient knowledge of those works constantly needing to be done in and about the streets, to enable him to see that the contracts and works for which the engineer is responsible are properly performed, and his orders obeyed. He must also observe and report to the engineer all cases of injury or dilapidation that happen to the public ways, or to any of the public property placed thereon, as well as all encroachments and wrongful proceedings of occupiers of property abutting upon the streets. The duties of the inspectors are performed chiefly under the direction of the engineer; they are, however, to take directions from the clerk to the commissioners, in relation to complaints of the scavenging, dusting, &c. Every inspector is directed to reside within his district, and to have his name and occupation plainly inscribed upon his door: he must carry with him a rule and memorandum-book, and have for reference copies of the standing orders of the commissioners, the regulations of lodging-houses and slaughter-houses; a list of hoards and scaffolds under licence, with the dates on which they expire; the names and addresses of the district-surveyors (under the Metropolitan Building Act), the contractors, turncocks, and foremen of gas, water, and telegraph companies, and any other memoranda useful in his business. He is to transmit his name and address to the commissioners within his district at the commencement of each year (fresh commissioners having then been appointed), and he must wait upon each of them twice in every week. He is to attend daily, as near as possible for a full hour, between twelve and one o'clock, at the sewers office, where the inspectors have a room in which they can transact business with foremen of contractors and other persons, in respect of works, complaints, &c., to take directions from the superior officers, and extract from the book kept for that purpose all complaints of defective pavements, neglect of scavenging and collection of dust, or other matters falling under his inspection. He is to attend all meetings of the commissioners and such committees as he may be requested to attend, and to enter his reports in a book to be laid upon the table previous to the chair being taken.

As regards the property vested in the commission, the inspector is to see that the pavings are maintained in a safe and proper state, and when he hears that any accident whatever has happened, and is alleged to be owing to their defective condition, he is immediately to inspect the place and report to the engineer, and not to alter it without a special order; he is to see also that all street name-tablets, posts, columns, channels, and other ironwork, are kept in proper order, and whenever they require renewal he is to obtain orders from the engineer for that purpose. As regards works, he is to see that all new contracts for paving or other matters, and all repairs, are properly performed, and to measure up and give vouchers for the same, and to give no orders for works, except mere jobbing repairs to pavings, without proper authority. When streets must be stopped for repairs, he is to give due notice to the engineer, who arranges with the police for the diverting of the traffic, and to the inspector of sewers in respect of interference with gulleys and shafts. When pavements have been disturbed by gas, water, or telegraph companies, he is to see that the trenches are properly filled in and the paving made good, and the same when the pavement has been displaced for hoards and scaffolds. He is also to carefully inspect the streets daily, and the courts and alleys at least twice in every week, to see that the scavenging is well performed, that the public urinals have been swept and washed, and that the streets are watered in the manner and at the time stipulated in the contract. In cases of his observing any danger to the public from dilapidated buildings, he is to give immediate notice to the district-surveyor of buildings, and if, necessary, to the police, and to have a hoarding placed for the protection of the public, if that shall seem needful. In respect of projections over the public way, he is to see that no parts of any shop-front, or any appendage thereto, nor any cranes, cellar-flaps, reflectors, or other projections, are made without permission. That no hoards or scaffolds are erected without a licence, and that they are removed when the time for which the licence has been granted expires. Upon observing any interference with the public way for which permission has not been given, he is immediately to serve notice upon the parties to discontinue the works, and to apply for permission. When a notice of any description has been served by him, he is carefully to indorse the counterfoil with particulars of service immediately, and to note the necessary facts in his memorandum book, to enable him to give evidence before the magistrates thereon.

As regards buildings, he is to report all cases of houses being burnt or pulled down, and to carefully sketch and measure the lines of frontage, that the rights of the public may be preserved; to ascertain the names of the owners, architects, and builders employed upon new buildings, and report in writing to the engineer. He is also to see that all alterations to the numbering of houses that may be ordered are properly carried out, and that no alterations are made without such orders. These are the ordinary duties of an inspector of pavements. They demand considerable powers of observation and a methodical arrangement of time; it is essential that they be well performed in order that the state of the city may be at all times known to the authorities. The inspector is liable to be checked in the performance of them by the observations of the engineer and of the commissioners, whose places of business are distributed over the districts, by their neighbours who complain to them, and by the occurrence of accidents which may follow upon unobserved derangements. The police also give immediate notice of any defect that is likely to produce danger to the public, and, if necessary, station an officer at the point where the defect exists.

Inspection of Sewers.—There is one inspector of the 48½ miles of street sewerage within the City. The main sewers under the charge of the Metropolitan Board of Works being excluded from his department, and from the above measurement. The inspector acts solely under the direction of the engineer to the commission. He takes charge of the reparation, jobbing works, and cleansing of sewers, gulleys, ventilation, &c.; also the construction and maintenance of such portions of the house drains as lie beneath the public ways. He must reside within or near to the City, and attend at the office of the engineer every day, or as he may be directed; he is also to attend daily at the sewers office, extract from the book all complaints that are within his department, and have the same attended to forthwith. He is to make such personal examinations, and take such measurements, sketches, and levels of sewers, as may be required of him; to give directions for the flushing and cleansing, and be responsible that it is properly carried on; to measure, superintend, and check the accounts for private drains beneath the public way, and also other works to sewers, and deliver the bills to the engineer for examination; he is also to superintend any gauging of sewers that may be ordered. He must be out early or late, as may be required by the nature of the work that needs inspection, having no fixed hours, but it is supposed that he will be occupied for eight or ten clear hours daily. The engineer has also a clerk of works over the new sewers that require to be constructed; and there is a foreman to superintend the flushing operations that are carried on by the contractors to the commission.

Inspection of Gas.—One inspector is employed under the engineer to examine by night into the manner in which the gas companies perform their contracts for lighting the public lamps; to check the meters, and to ascertain the causes of any defects. Every morning also, the commissioner of police furnishes the engineer with a list of all the lamps that were observed by the officers to burn dimly or to have been in any other way defective during the previous night, and the inspector is at once directed to examine and report upon each particular case.

Inspection of Sanitary Works.—There are two sanitary inspectors in the City, who act under the medical officer of health, but are also to take instructions from the the engineer in cases where there is any difficulty respecting the details of constructing or amending drains or pavements. The conditions as to residence and attendance at the sewers office are generally similar to those already given for inspectors of pavements. The inspector is to attend the medical officer of health, and assist him in sanitary inspections; to serve notices and orders for all sanitary works, except those to the common lodging-houses, cow-houses, and slaughter-houses, and keep proper records of service; to see that the orders are carried out, and to report to the medical officer once in every week upon all cases of failure or neglect in executing the orders. In cases of doubt or difficulty as to the work, he is at once to consult the district inspector of pavements, and, if necessary, to report to the engineer.

The inspection of cow-houses, common lodging-houses, slaughter-houses, and meat of various kinds, is carried on by officers of the commission in like manner; the rules under which they act are tolerably stringent, and, so far as we can ascertain, they are enforced. Prosecutions are frequently instituted for breaches of regulations by the public; and the contractors to the commission are not unfrequently brought up and fined heavily, upon the evidence of the inspectors, for the non-performance of scavenging and other works, that require to be attended to day by day. It is difficult to overrate the importance of an efficient system of inspection in a town of many inhabitants and much traffic, and we have dwelt upon the details of the system as established in the City of London, because it has with great care been developed, step by step, as necessity arose, and because it is carried out with extreme regularity, and seems well adapted for the object in view. We propose to treat in the next place of the duties of the higher officers of the commission, and of the practice in respect of the several departments of sewerage, street management, public improvements, and works undertaken for the protection and preservation of the public health.

(To be continued.)

LISTER'S IMPROVED THEODOLITE FOR SETTING OUT SURFACE-WIDTHS.

A NEW instrument has recently been brought under our notice, which evidently possesses several novel and important features. It is a combination of the theodolite and level, but while serving all the ordinary purposes of the two instruments, is specially designed for setting out mechanically, without recourse to calculation, the surface-widths, or slope-pegs, for denoting the top of slope on cuttings, and the foot of slope in embankment, required in the execution of railway, canal, and other earthworks.

The ordinary method of setting out surface-widths hitherto practised is that generally described in works treating of the subject, which involves the use of the level, and a distinct operation, with considerable calculation, for each half width separately, and which in rough and sidelong ground requires to be frequently repeated in each case before the required point is found, thus rendering the operation not only tedious, but very liable to error. By the following explanation of the instrument and its application it will be seen that the whole operation, being simply mechanical, little or no calculation being required (not any, if tables be used), the liability to error is reduced to a minimum, and the manipulation of the instrument is rendered simple and expeditious.

The main feature or novelty of the instrument consists in a modification of the ordinary theodolite, by giving to the telescope a horizontal action on the spindle or axis of the vertical arc, instead of being fixed to it, so that when clamped by the vertical arc to the angle or inclination of the slope required to be set out, and fixed in this plane at any point, the telescope will revolve in the plane. It will thus be readily seen that, the telescope revolving in the plane of the slope, any point on the surface in that plane, when the line is straight, will be cut by the cross wire of the telescope, and thus the widths at the several chainages, or at any intermediate point where the nature of the ground would necessitate a width being put out within the range of the telescope, would be at once determined on either side of the instrument, to the next change of gradient. When the line is on a curve, each point is determined by tangential angles, the method of procedure being precisely the same as setting out an ordinary curve on the centre line, with this addition, that the telescope must be depressed to the vertical angle which the slope line assumes to the chord at each point, or as seen from the instrument. This angle varies from the angle of inclination at the tangent point, *i.e.*, at the instrument, to zero, or a vertical line when the chord is at a right angle to the tangent, or when the curve has been traced round to one-half its circumference, and may be found for any point from the following equation:—

tang. of vertical angle $= r \times$ cos. tangential angle,

r being the ratio of slope $\frac{1}{2}$, 1, $1\frac{1}{2}$, &c. But this calculation is obviated by the use of certain scales of tangents, graduated on the vertical arc of the instrument, for the several ratios of slope; it being only necessary to clamp the vertical arc to the tangential angle for each point respectively.

The only calculations required in the operation are those for the tangential angles, which are readily found by dividing constant 1719 by the radius of the curve in chains, which gives the angle in minutes for the first chain in the curve. The angle for any other point is found by multiplying this angle by the distance in chains, or by $\frac{D \cdot 1719}{R}$, D being the distance in chains; but the use of tables, particularly those by Kennedy and Hackwood, which give the angle for every chain up to 20, for any curve, obviates any calculation whatever. Thus the widths on a curve may be almost as readily set out as those on straight, as the manipulation of the instrument is easily performed during the time the assistant is driving the peg, and walking from one point to another. In curves of large radii, the variation of the vertical angle, for some distance from the instrument, is so slight that the depression of the telescope is practically immaterial; but in curves of smaller radii, and in those of larger radii when the widths to be set out are at a considerable distance from the instrument, it is necessary that the variation be attended to.

The instrument is perfectly adapted to all other purposes. It is not a transit, but is simply reversed by releasing the telescope from its securing cam, and turning it horizontally on its axis till the opposite cam is in place. It is strong, yet light and compact, with a powerful telescope, and the cost does not exceed that of the ordinary theodolite.

The general advantages of the instrument, as stated by the inventor, are:—1. Its simplicity of manipulation. 2. As avoiding tedious calculation, and consequently, liability to error. 3. By its means surface-widths are set out much more expeditiously, as by one set of the instrument (if no obstruction occur) they may be set out to any distance on either side of the instrument, within the range of the telescope. 4. On sidelong ground, which presents no increased difficulty. Indeed, the real utility and advantage of the instrument can only be fully appreciated in rough and mountainous districts, where the ordinary methods become totally impracticable. Lastly, as combining in itself both the theodolite and level. The telescope freely revolving horizontally, as in the common level, independently of the other parts of the instrument, renders it perfectly adapted for levelling, and thus precludes the necessity of possessing both instruments—an important advantage in a pecuniary point of view.

APPLICATION OF THE INSTRUMENT ON THE GROUND.

When the line is straight.—In proceeding to set out a series of widths when the line is straight, first set out in the ordinary way (using the instrument as a level) a pair of widths as far as possible apart, or at any convenient distance, according to the nature of the ground; or, where practicable, put out the formation width at the commencement of cutting or bank, and make this one of the points established. Then clamp the telescope, by means of the vertical arc, to the angle or inclination of the slope, and set it at one of the points already determined, so that the cross wire shall cut the top of the peg, or coincide with the plane of the slope at that point. Then direct the telescope to the distant peg, or other point determined, adjusting it by means of the screws on the horizontal arc, when it will now revolve in the plane of the slope, the cross wire coinciding with the surface-line of that plane throughout the whole distance to the next change of gradient, which may now be "nicked out," or the batter-pegs put in on either side of the instrument, as far as the range of the telescope will admit. The operation is then repeated for the other side of the cutting or bank, the two points for a basis being already found by the former operation.

When the line is on a curve.—In setting out widths on a curve, first accurately lay off in the usual way, by means of a cross staff or optical square, a "square" line, or line at right angles to the tangent of the curve at each chainage peg in the centre line. Then set out the pair of widths as a basis, and fix the instrument at one of them, as described in case of straight. Having done this, calculate the tangential angle for the distant peg, $\frac{D \cdot 1719}{R}$ D being the distance in chains, and R the radius of the curve in chains (or refer to the tables). Clamp the horizontal arc to this angle, and the vertical arc to the same angle on the graduated scale, and direct the telescope to the peg. Clamp the lower plate. Unclamp the top plate, and the telescope when set at zero is now on the tangent line, and the method of procedure is the same as setting out an ordinary curve by tangential angles, as before described—that is, doubling the angle for the first chain for the second, and adding it again for each chain forward (or by using the tables), the vertical arc being clamped to the same angle for each chain respectively. The intersection of the cross wire of the telescope with the square line set off at each peg, determines the surface-width at that point.

The instrument is the invention of Mr. James Lister, C.E., Clare, Suffolk.

ARCHITECTURE AND PUBLIC WORKS ABROAD.

THE Royal Institute of British Architects have recently, through their foreign secretary, applied to their foreign members to communicate information as to the state of architecture and the progress of works, public and private, in their respective countries, and several foreign members have already complied with the request. The Chevalier I. da Silva, president of the Association of Portuguese Architects, communicates the following observations. Writing from Lisbon, 23rd December, 1864, he says:—

"Nothing very important in architecture has been done in this country since the construction of the church of the Estrella, built by Queen Donna Maria I., and the commencement of the new

Royal Palace of Ajudà, the public not having sufficient artistic taste to recognise the merit of good architecture. The Government, for its part, is not rich enough to undertake any great works, besides railways, in which our art could display its resources and offer something worthy of observation, and thus induce a taste for the Fine Arts among the inhabitants of Portugal. It is true that a château has been built for H.M. Don Fernando, at Cintra, but the building is rather a picturesque royal cottage than a palace, properly so called, for its architecture is more a caprice than an affair of taste pure and monumental. The most important private constructions have hitherto followed the taste adopted in rebuilding the city after the great earthquake of 1755—viz., that displayed by the architect, Frederic Londuvic, in the palace and convent at Mafra, a type which has been generally imitated, and become habitual for want of a better. However, of late, houses of better style and material have been erected, some with polished marble fronts, giving another character, while in their arrangement the endeavour has been made to satisfy the requirements of modern civilization. The façade of the new Chamber of Peers is already well advanced, and will be entirely of freestone; the architecture is not amiss, but the choice of the site for this façade, the way left for the principal entrance and the public service, are altogether faulty, even absurd, producing a very bad effect, unbecoming the palace of the Upper Chamber.

Great works will shortly be undertaken, as the palace of Ajuda is to be finished, but not according to the original design, which would have made it twice the length, and out of all keeping with the present domestic requirements of the Court. The works already in hand will be terminated by placing square towers at the two other angles, like those now built. The palace will be situated between the two Grandes Palaces, and the side fronts will face gardens, while their majesties' suite of apartments will overlook the river. In this construction something may be done to advance art, for there will be a fair opportunity for the display of talent and good taste, ample space being at command, while funds will not be wanting to render it an edifice perfect and fit for the habitation of the sovereign.

An astronomical observatory is also in hand, in a fine situation, on an eminence visible from all parts of the city. The plan presents no novelty, for it follows that of the Russian observatory, diminished by one half. It is so arranged as to answer the purpose in view, but, unfortunately, the architectural details are not the most classic. The pedestal of the monument to the memory of the great Portuguese poet Camoens is laid; but it is to be regretted that the place is irregular, and that the design was not calculated for it, while the style does not harmonise with the surrounding buildings. All this is against common sense, and shows at once that the monument is out of place in its present situation. It is, moreover, a pity that the first erection of a monument here to commemorate a great man should result in a failure, as it may deter us from raising other memorials to those who have rendered good service to their country.

The chief station of the railways in Lisbon is well forward, and will be finished next year. Its architecture is mercantile (permit me to use the word), for more thought has been bestowed on making a vast building well lighted, rather than a monumental one, such as would become a great capital. The roof of iron is very strong and carefully constructed. I need hardly say it was made in your country, for whenever we want anything first rate in such matters, we have always to send to England.

We shall shortly have an artistic exhibition of designs sent in competition for the monument to the Emperor Don Pedro, which will be placed in the Great Square bearing his name. It is said that there will be more than seventy models by artists of various countries. The Commission has them all photographed, to form an album, and by the comparison judge of the artistic merits of the designs, and let the public know if the prizes have been awarded to those which are considered to possess the most merit. When this exhibition takes place, I will take care to send you timely notice of the relative merits of the models.

Among the number of private constructions now in hand in Lisbon, I must not forget to mention the fine palace of the very opulent banker, M. Eugenio de Almeida, peer of the realm. It is the only one which shows becoming architecture; and it is more remarkable, because that gentleman is the only one of all the rich men in our country who has built a palace without regard to the cost, and the time required for its completion. The proportions of this palace are very good, and it is adorned with sculpture, while the interior is richly gilt, &c. It may be said to be the finest as yet in Lisbon, both for good taste, magnificence, and artistic merit. But if even these modern constructions did not evince a favourable disposition for architectural progress in this country, the very excellent restoration now in hand of the convent and church of the Batalha would alone be a striking instance. M. Lucas Pereira, a Portuguese architect, has superintended the works for the last nine years, with much skill and scrupulousness, worthy of all praise, preserving the character and the ornaments so as to make them all appear of the same epoch, whilst he has most carefully attended to the modern construction, so that it may last for many future ages.

It is to be regretted that the coloured glass, wanting on the side bays of the choir of the church, was not made good with imitation of the fine coloured glass which existed of the time of the building of this cathedral. But this was not the fault of the architect, but arose from economy—false, indeed, in this instance, for in works of this importance in historical edifices, such narrow regard for expense should not be indulged.

To conclude. Our Art seems to wish to make an effort to abandon the ancient routine which the taste of monastic buildings had impressed on all the constructions of this country. It appears also that the public begins to feel the necessity of having more of the comfortable and the elegant in order to live more at ease. And in order to obtain that, it is obliged to ask from the Fine Arts the assistance necessary which they alone can give to those who have the good sense to spend their money profitably and agreeably, and to concur for the civilization of their country; and this civilization has been always marked at all epochs by the progress of architecture, which transmits down to posterity the fame of the people who have successfully cultivated it. For my part, I do all I can that our art may follow the general development of our age. I have just commenced a course on the Monumental Architecture of Ancient Nations in the Institute of Portuguese Architects, and, in order to attract the attention of the public, I have in preparation large coloured drawings of ancient monuments. It is good news for the Fine Arts in this kingdom, that his Majesty the king has just made the munificent gift of 125,000 frs. annually to purchase objects of art for the Portuguese Academy."

"The grand works carried out in Paris of late years have excited the emulation of the chief towns in France, which have desired, like the capital, to form for themselves broad lines of communication, public promenades, monuments, &c. &c. Marseilles has not remained behind. Great works, public and private, have been undertaken. Of these, either executed or in hand, I now give a summary. First, the ports. The old port was insufficient, having only 270,400 metres* of surface and 2200 metres of unloading quay. New ports have been formed to the west of the city, in the Anse de la Joliette, by means of jetties formed of blocks of stone, natural and artificial. There are three of these ports—the Joliette, the Docks, and Napoleon. Their united area is 590,500 metres, and development of quay 9000 metres. They have cost about thirty-four million francs.† The area of these three ports united is more than double that of the old port. If to the cost of constructing these ports we add that of the maritime establishments which complete them—the annexe of the Port Imperial (now constructing), which will cost twenty millions, the Basins Radoud, four millions, the docks and entrepôts, which have cost twenty millions—we arrive at a total outlay of sixty-four million francs. A new quarter has arisen north-west of the city, where these ports are situated, by means of broad and direct roads, bordered by buildings for various industrial purposes, and by dwellings for the maritime population.

Among the most important formations of thoroughfares must be named the prolongation of Rue Canebière on the site of Rue Noailles, and the formation of Rue Impériale, intended to form the shortest line of communication between the centre of the town and the new quarters of the docks. Several streets, considered insufficient, have been widened, both in the old and in the new town. But in order not to enter on superfluous details, I will only speak of Rue Noailles and Rue Impériale. Rue Canebière, 30 metres wide by 250 metres long, commencing at Cours Belzunce, and going to the old port in a westerly direction, has been prolonged eastward, of the same width, and an equal length, on the site of Rue Noailles, which was only 6 metres wide. The formation of this new Rue Canebière, which retains the ancient name Noailles, has occasioned the demolition of ninety-four houses,

* Metre = 3·28 feet, English; three metres, in round numbers, = 10 feet.
† Million francs, in round numbers, = £40,000.

at a cost of nine million francs, and the ejectment of 2500 persons. These two streets, Canebière and Noailles, which are now one, form the grand artery of the Phocean city. Rue Imperiale, recently inaugurated by the Emperor, is 770 metres long by 24 wide. It cuts obliquely through the old town in a north-west direction. This considerable cutting has occasioned the exappropriation and the demolition of 935 houses, inhabited by a population of 16,000 souls, or workmen, who have migrated to the houses built in the suburbs of the town. The cutting away the highest part of the crest of the hill on which the part of the old town traversed by this street was built, was 20 metres deep. The average quantity removed by this cutting, over the whole surface, was 1,500,000 cube metres, partly breccia, tuffo, and ground. During the work, some ancient tombs of soft limestone and some stele, of small dimensions, supposed of the Phœnician epoch, were found, also some medals, among them one of silver of an unknown Greek colony; and lastly, towards the old port, the hull of an ancient barque. But all these discoveries are of very little archæological interest. The total expenditure for the Rue Imperiale amounted to the sum of twenty million francs. At present a new cutting through, which is not without importance, is being executed. It is for the purpose of forming a carriage communication between the north and south quarters of the town. With that view, the Cours Lieutaud is being prolonged to the Boulevard du Musee, on a length of 500 metres, and a width of 24 metres, traversing obliquely Rue d'Aubagne, Rue Neuve, and Rue Château Redon. Eighty houses are exappropriated; the cost will be 4,200,000 francs, including the removal of 100,000 cube metres of ground. Population displaced, 3400 inhabitants.

Several boulevards have been opened, conducing to the embellishment of Marseilles; but I will only mention the magnificent promenade, the Prado, which is now completed, by the Cheminde la Corniche, and the Park Borely. The promenade du Prado is 3450 metres long, in two divisions. The first, starting from the Place Castellane, goes south for a length of 1620 metres and a width of 80 metres, with six rows of trees, and abuts on a vast circular space 180 metres in diameter, with a basin and fountain in the middle. The other division, turning west, 1830 metres long and 50 metres wide, with four rows of trees, starts from the above-named circular space (Rotonde), and abuts on the sea beach, where the Chemin de la Corniche begins, which follows the line of the coast, passing by Roucas Blanc, le Vallon de l'Oriol, Endoume, to the Bains Catalans. Thence, crossing through Fort St. Nicholas, and along the quays of the old port, we come to the centre of the town. The whole length of the drive from Rue Canebière to the same point again, is 11,250 metres. The Chateau Borely, a recent acquisition by the town, is situated at the extremity of the Prado, and south of it, on the right bank of the Huveaune. In this property (of 520,000 metres of surface) admirably situated, a fine park with clumps of trees has been formed, besides cascades, sheets of water, and a racecourse. The principal building, one of the last century, has been appropriated as a National Museum. All these items have cost more than a million francs.

The most important public buildings finished in the last fourteen years, are the Cellular Prison for 200 prisoners. It occupies an area of 7000 metres, and the building has cost 500,000 francs. It is situated in the Quartier Chave. The Prison, or Maison d'Arret, in the Quartier St. Pierre, for 500 inmates. The area of the buildings finished is 10,000 metres. Cost 600,000 francs. The new Civil Hospital (de la Conception) in the same Quartier St. Pierre, holds 780 patients. It has cost 1,600,000 francs, and occupies an area of 22,000 metres, including courts, outbuildings, and airing grounds. In the same quarter, the Lunatic Asylum, calculated for 900 patients of both sexes, built on an area of ground of 30,000 metres, including the various courts, airing-grounds, the chapel, the official residence, attendants' lodgings, and outbuildings. The outlay has been 1,500,000 francs.

The Military Hospital in the Rue de Lodi, occupies an area of 11,000 metres, including the cour in the centre. It is arranged to receive 600 patients. It has cost one million francs. The Barracks for the Gendarmerie, on the Prado, capable of holding four brigades, occupy an area of 3500 metres, and has cost 70,000 francs. The Cavalry Barracks, for a squadron, and the Artillery, in the Quartie Mempenty. The Infantry Barracks, for a battalion, in the Quartier St. Lambert. The great Infantry Barracks, for a regiment of 3000 men, in the Quartier St. Charles; and near these important barracks an arsenal, magazine for field trains and equipage, and building for repairs; vast establishments, which have been executed by the military engineers, and of which the cost may be estimated at five million francs. The Exchange and Tribunal of Commerce, containing the Chamber of Commerce and its dependencies, meeting-rooms and dependencies, the Registry of the Tribunal, and the Syndicates of the agents and brokers. It is built fronting the Rue Canebière, the centre of commercial affairs, on an area of 4800 metres, for which site 4,800,000 francs have been paid. The building has cost 3,200,000 francs, total outlay 8,000,000 francs. The Chamber of Commerce has paid all this outlay.

The Palais de Justice, for the Tribunal de Première Instance, has its principal façade ornamented with a Grecian Ionic portico of six columns, raised on a flight of twenty steps. It is situated in the Cours Bonaparte, on an area of 2800 metres. Cost 1,800,000 francs. The Mont de Piété, a large building in the centre of the town, on an area of 3000 metres, with a court in the centre, has cost 600,000 francs. The Faculty of the Sciences, on the Promenade des Allées de Mëilhan, has cost for building and occupation, 250,000 francs. The Communal School, on the Boulevard des Dames, on a site of 1250 metres, containing infants' cribs, refuge, girls' school, orphanage for twelve hundred children, with workshops and lodgings for twelve instructresses; the outlay for its construction has only amounted to 260,000 francs. A zoological garden in the Quartier Chartreux, occupying a western site, and very picturesque, with an area of 50,000 metres, has caused an outlay of a million francs. The new cemetery in the Quartier St. Pierre, occupying an area of 228,000 metres for the Catholic, and 12,000 for the Protestant division—together 240,000 metres. Purchase of the ground, 527,500 francs; works of adaptation hitherto, 150,000 francs—total actual outlay, 857,000 francs. A synagogue in rue Breteuil, in half Byzantine style, has cost hitherto 400,000 francs.

Several churches, chapels, and convents, built in the town and in the outskirts, in Roman, Gothic, and Renaissance styles; some on the Basilican plan. These various religious edifices, in general of little value in an artistic point of view, have occasioned a total outlay which may be estimated at about three million francs. The buildings in course of erection are:—The new cathedral (in the Byzantine style), of which the Emperor Napoleon III. laid the first stone in 1852; a monument very remarkable for it size and its religious character, 130 metres long by 40 wide, not including the projections outwards of the transepts. Total area, 6500 metres. The cost, according to the design, will amount to about twelve millions—four millions have hitherto been expended. The building is up to the springing of the internal vaults. It is constructed in courses of hard stone, externally white and grey (the latter from Florence), internally white and red (the red being marble from the Department du Var). All the vaulting will be of brick, to receive fresco paintings. The internal columns will be of coloured marble. This monument will have four cupolas, two bell-towers on the façade, and a great number of turrets around the cupolas. It has been designed, and the erection is superintended, by M. Leon Vaudoyer, architect of the government, and corresponding member of your institute. The Museum of Paintings and the Museum of Natural History, two separate piles of buildings, but connected by a circular gallery ornamented with columns, with a large reservoir in the centre with groups of statues; cascades and basins in the middle, grass plats, plantations and flower-beds complete the effect of the building, which is situated on an elevated spot, with a carriage-approach by easy inclined planes. Its style is that of the Renaissance. It occupies an area of 4000 metres, and will occasion an outlay of three million francs. The Public Library and the School of Fine Arts, building to the south of the Imperial Lyceum, upon a plot of ground of 2800 metres, including courts and dependencies, and separate dwellings for the directors of the library and of the school: estimated outlay for the construction only, 1,500,000 francs. The Chapel of Notre Dame de la Garde, much venerated by our sailors, situated on the top of a hill south of the town, rebuilt in the Byzantine style. It is crowned by a cupola over the sanctuary, and has a square bell-tower at the western entrance, on which will be placed a colossal statue of the Virgin, of bronze gilt. The cost of construction has thus far amounted to 1,300,000 francs, leaving still 600,000 for its completion. The total sum for the rebuilding of the Chapel of Notre Dame de la Garde will be 1,900,000 francs. The imperial residence, built on the promontory of the old Anse de la Reserve, south-west of the entrance to the old port, a magnificent situation overlooking the ports. The whole of this residence occupies an area of six thousand five hundred metres; the building 320 metres. The outlay, purchase of the ground and construction, will come up to two million francs.

The new Prefecture—a large hotel with a court in the centre and a garden to the east—containing the residence of the Prefet, apartments of state to receive the Sovereign, rooms for the Underprefet, general secretary, all the offices, rooms for the archives, and their dependencies. This vast edifice, in the mixed style of the Renaissance, occupies a hectare* of ground, including courts and garden. The purchase of the ground has cost 6,000,000 francs, and occasioned the exappropriation of thirty large houses and the removal of four hundred inhabitants. The works of construction executed up to the present time have cost 2,800,000 francs. Total outlay, 8,500,000 francs. It will cost for the finishing of the building, 1,800,000 francs, and for the internal decoration and furnishing, 700,000 francs. Total supposed outlay, about 11,000,000 francs. Lastly, the Hôtel Dieu, an hospital situated in the centre of the old part of the town, has been restored and completed after the plans of Mansard. The approaches to this ancient hospital have been disencumbered by pulling down the houses which obstructed the enlargement of the building. The outlay for the works done, and to be done, may be estimated at 2,500,000 francs.

Other projects are being considered. New thoroughfares to be cleared through the old town, and the enlargement of the Hôtel de Ville, now inadequate for the wants of a city whose population is increasing every year in a considerable proportion. This population, which under the First Empire was only eighty thousand souls, now exceeds three hundred thousand. Of course private buildings are singularly multiplied, owing to this increase of population, as well as the opening of new quarters of the town, and the thoroughfares cut through the old parts of it. Many houses with three windows and with two in front, and of a very melancholy appearance, have been demolished and replaced by spacious houses of six storeys, mostly enriched with mouldings and ornamentation. Not that all these buildings which have pretensions are marked with the sign of art and good taste —such is far from being the case; the result, however, has been progress in workmanship, and in the artistic tendencies of the population.

As regards the public buildings which I have enumerated and briefly described, they are not all irreproachable; but there are some remarkable ones among them, such as the Cathedral, the Museums, the Library and Ecole des Beaux Arts, the Chapel of Notre Dame de la Garde, the Barracks, the Prisons, the Lunatic Asylum, the Palais de Justice, and the new Prefecture. I will not say anything about the Exchange and Tribunal of Commerce, being the architect who designed that important monument. The establishments constructed by the State engineers, the ports, docks, &c. &c., are perfectly appropriate, and deserve commendation for good arrangement and skill in satisfying the demands they were required to provide for.

From what has been said, it results that the aggregate of the works undertaken at Marseilles during the term of fourteen years, at the expense of the State, of the Department, and of the Corporation, amounts to a total outlay of about 160,000,000 francs†—in itself a handsome figure. But what would it be if I added the outlay caused by the construction of the military establishments, tobacco manufactory, works and factories; in short, the construction of habitations on the new lines of thoroughfare, and in the various suburbs?"

STOCKMAN AND SCOTT'S IMPROVEMENTS IN FOUNDING SUBMARINE STRUCTURES.

Improvements in the means of constructing sea and river embankments, walls, and similar structures, have engaged the attention of engineers and inventors for a lengthened period, and great professional skill and ingenuity have been employed in the effort, the object being to provide an efficient and economical substitute for the costly alternative of timber coffer-dams.

One of the most recent and, so far as yet tested, successful inventions for this purpose, forms the subject of a patent recently granted to Mr. B. Pryor Stockman, C.E., and Mr. J. Sheppard Scott, from the specification of which we extract the following description:—

"Our invention relates to the preparation and providing of foundations for structures required to be erected in water or in marshy or wet ground, and is applicable in all cases where coffer-dams have hitherto been found necessary. According to our invention we propose to form a foundation platform of iron, stone, timber, or other suitable materials, supported upon and securely fastened down to cylinders or piles or other suitable supports, and made sufficiently strong and water-tight to admit of the superstructure being erected thereon, and resisting the upward pressure of the water. A tank dam is to be attached to this platform, of which the platform itself forms the water-tight bottom. By this arrangement a secure and dry chamber is obtained, within which the structure can be erected. As each section or length of the structure is completed, the sides and ends forming the tank dam may be removed, leaving the structure supported by the foundation platform. In cases where the platform might be liable to oxidation or rapid decay, or required to be removed, "relieving" or "ground" arching or concrete or stone blocks may be used in the lower part of the structure, which would form a sufficient foundation or support, bearing directly on the cylinders or piles in the event of the platform being entirely destroyed or removed.

The essential feature of our invention consists in the means of forming foundations for embankments, sea or river walls, moles, breakwaters, piers and abutments of bridges, lighthouses, or any other kind of structures or buildings of brick or stonework, or of any other materials that have to be erected in water or on the margins or shores of lakes, canals, rivers, seas, or on their beds, that is, wholly or partly immersed in water, so that such structures can be formed, built, or erected in an enclosed dry temporary chamber, without resorting to the usual method of driven or sunken coffer-dams and excavated foundations within them. We make use of the various modes of forming pier or pile supports that have hitherto been in use, such for instance as sinking cylinders, and filling them up solid with concrete, brickwork, or other suitable filling up; or we use screw piles, iron, or driven piles, corrugated iron piles, or a natural rocky bed, an artificial bed of rubble, or any means suitable to form a support or bearing for the upper work, which in detail is constructed as follows:—We construct and use a "sealed platform" and a "tank dam," and these two combined together comprise our invention. The sealed platform may be constructed in various ways, according to the requirements and the means and materials at hand; for example, it may be of cast or wrought iron in the form of girders, joists, and plates, or of groined plates, buckled plates, or of cast or wrought iron, or both combined, of any suitable form and arrangement sufficient to sustain the load of the structure, and to keep out the water. Round the margin of the "sealed platform" there are vertical sides and ends attached to it, forming with it a "tank dam," the sides and ends are of wrought or cast iron, so formed and arranged as to resist the pressure of the water from without, and to enclose a convenient chamber in which to build, construct, or erect the permanent structure. The joints in the "sealed platform" and "tank dam," are cemented, caulked, or packed, or made water-tight in any other way, and fastened by bolts and nuts, rivets, or other methods of ensuring a proper fastening. The "sealed platform" and "tank dam" are lowered on to the supports or bearings already described, and fastened to them or not, as the case may require, or constructed thereon. The permanent structure, of whatever form or kind it may be, is then erected with enclosed space, and when completed the sides and ends of the "tank dam" are removed, leaving the structure founded on the "sealed platform."

The following are some variations in the details of the "sealed platform" and "tank dam:"—The sealed platform may be made partly or wholly of other materials than cast or wrought iron, such for instance as partly or wholly of timber, or of slabs of stone, slate, or brick arching or groining, all of which are set in a girder framing of cast or wrought iron or timber, or otherwise bound together in shape and position. The "tank-dam" sides and ends may be of timber, or of timber and iron combined, or of other suitable materials. We also form a "tank dam" by sinking the sides and ends deeply into the bed under the water, or by attaching them to supports or bearings, in which case the "sealed platform" is made by a solid mass of concrete,

* Full 2½ English acres. The hectare is 10,000 square metres, or 11960·38 English square yards.

† £6,400,000 English.

rubble, masonry, brickwork, clay, or other material, filled in up to the level of the footings of the permanent structure to be erected, and the upper surface of such filling-in is then left level to receive the structure, or prepared by a paving of iron or timber, or by other means, either level or in the form of centering, so that the structure to be erected will have its weight transferred by means of relieving arches or groining directly on to the rigid portions of the supports or bearings, such as, for example, the cylinders or piles. We sluice out the "tank dam" when necessary by means of valves or openings. We also provide against any upward pressure due to a head of water by loading the "sealed platform" all over, or by anchoring or fastening it down to the supports or bearings, or by pumping the accumulating water from under the surface of that portion of the "sealed platform" exposed to its action, or we leave vents for the water to ooze through to prevent the static pressure due to the head forcing up the "sealed platform." We also use where required sheeting piles of timber or iron, or plates of iron, either plain, buckled, or corrugated, sunk into the bed under the water, and between the pile or cylinder supports around the margin, to prevent the bed from being scoured by the action of the tide, and also to prevent the water from penetrating and accumulating quickly under the sealed platform.

Our invention is intended as a substitute for either of the methods of founding a permanent structure called "tide work" and "hydraulic work," wherein the structure may be founded on supports or bearings, such as we have described, but without a "tank dam," the "tide work" process only allowing the building to go on during the times the water is below the level of the work, and the "hydraulic" process going on actually in the water, that is to say, by the aid of diving or other submerged means. Our invention, therefore, differs from these processes in so far as we construct and use a "tank dam" as already described, forming a dry chamber, in which the permanent structure can be erected. By preference the "tank dam" is made to extend in height above the highest water level, so as to enable the permanent structure to proceed at all states of the tide in the sea or tidal rivers; but we also use a "tank dam" of less height with a means of sluicing, so that a structure can only be erected dry within it while the water is below its top edge, the time of working per day being determined by the height of the tank dam."

Messrs. Scott and Stockman's patent is now being tried on the foundations of part of Mr. Ritson's contract of the Works of the Thames Embankment (No. 2 Contract.). The experiment would have been completed before this time, but for the fact that Mr. Ritson had commenced the old fashioned timber puddle coffer-dams, before it was introduced, on his work.

Mr. Ritson's timber dams have been admirably constructed, and they have proved perfectly successful. The plan now before us has, therefore, suffered delay in consequence; but from what we have seen of the plan, we think it cannot fail to answer its purpose well, and to be a more expeditious, economical, and at the same time thoroughly substantial mode of founding the embankment wall than any other hitherto tried. Of the patentees, we may say that the first-named, Mr. Stockman, is known to the profession as an experienced engineer.

Railway Bridge over the Seine.—The Western Railway of France is now constructing a short line to connect the town of Rouen directly with the Paris and Cherbourg railway, and the work includes a bridge over the Seine near Elbeuf. This construction will be more than 650 feet long and 18 feet wide, and will rest on five series of tubular cast-iron piles, with intervals of about 160 feet between them. The bridge itself has been constructed on the banks of the river, and is now being placed on the piles, the entire structure, 200 metres long, being pushed forward by means of very simple arrangements from one side of the river to the other. The operation was commenced some time since, when the end of the bridge rested on the third set of piles after eighteen hours' work. The weight of the bridge is given at 1000 tons, and the movement was given by sixteen men. The bridge is the work of Messrs. Schneider and Co., of Creusot, who adopted the same method in the case of the viaducts of Fribourg, in Switzerland, of Romans, on the Isère, and of Saint Just, on the Ardèche.

INSTITUTION OF CIVIL ENGINEERS.

Jan. 24.—The Paper read was "*Account of the Docks and Warehouses at Marseilles.*" By T. Hawthorn.

It was stated that the port of Marseilles comprised five docks in actual use, and one in course of execution. The old dock, or old port as it was generally termed, constructed about the time of Louis XV., was formed out of an inlet of the sea. It was 1100 yards in length, with a mean breadth of 120 yards, and near the entrance the depth of water was from 21 to 22 feet. The dock de la Joliette, the first constructed basin of the new port, was 500 metres in length by 380 metres in width. The dock du Lazaret, which served exclusively for customs purposes, came next, and then the dock d'Arene, succeeded by the Napoléon dock, 380 metres in length by 300 metres in width, recently completed by the State, who were at present engaged in the construction of the dock Impériale, as well as graving docks, which would be executed to the level of the quays by the Ponts et Chaussées, and then be handed over to the "Cie. des Docks et Entrepôts." All these basins were formed by constructing moles in the sea, a pier, or breakwater, parallel to the shore, constituting the seaward side of the enclosure. The earthwork for the moles of the Joliette and Lazaret, as well as for filling in the space upon which the magazines and warehouses were built, was taken, for the most part, from a hill immediately to the east of the docks. This hill, of nearly 100 feet in height, might literally be said to have been thrown into the sea; two million cubic metres of 'deblais' having been thus employed. The mole Arene was formed with 'deblais' from the Rue Impériale, a new street cut through the old town to the level of the new town, which involved the excavation of 1,200,000 cubic metres. Previous to the filling-in of the Lazaret, excavations to the depth of from 8 to 10 metres were made in some places, to remove a mass of slimy earth, that had accumulated at that part for many years, from the residue of old soap works. This earth was so impregnated with a green coloured matter, that obnoxious gases were frequently given off, producing illness among the labourers.

In the construction of the pier and breakwater, an embankment was first formed of hard calcareous stone, mostly taken in barges from the islands opposite the port. This stone was sorted in classes thus, rubble weighing from 20 lb. to 250 lb. each piece; first class from 250 lb. to 1 ton 2 cwt. each; second class from 1 ton 2 cwt. to 3 ton 15 cwt. each; and third class from 3 ton 15 cwt. and upwards. The smallest material was used for the core, or hearting, of the embankment, the larger pieces being successively added. This embankment was levelled at a height of 2 metres (6 feet 7 inches) above low water, the surface being 7 metres in width, and the slopes having an inclination of 1½ to 1 in height. At a depth of 8 metres under low water, the width of the embankment was increased to 7·34 metres, horizontally towards the sea, in order to receive the large concrete blocks, placed on it promiscuously to break the force of the sea. The artificial blocks had a width of 10 metres at the level of low water, and they attained a mean height of 3·8 metres above the same level. On the inside of the pier, a quay, 30 metres in width, was formed of natural blocks, with a wall in front, the latter having its foundations 6 metres below the water line. The embankment had a slope towards the dock of 2 base to 1 in height, and as its formation progressed it was from time to time solidified, by placing on it artificial blocks, in tiers one above the other, by means of a floating crane or derrick. These blocks were generally allowed to remain about three months.

It having been ascertained, by experiment, that blocks weighing 20 tons each, and measuring 10 cubic metres, could not be moved by the most violent seas in the Mediterranean, artificial blocks of concrete were made of an average weight of 23 tons; their dimensions being 2·4 metres long, by 2 metres wide, and 1·5 metre deep. These blocks were composed of two parts of hard, broken, limestone, to one part of cement; the cement consisting of five parts of sand to one of lime. These materials were mixed in portable iron cylinders, made to rotate by means of a belt connected at pleasure with a steam engine, which also drove the stones for mixing the cement. After the concrete had been well worked, the mixture in the cylinders was emptied into wooden moulds, which could be detached from the blocks. The moulds were so constructed as to form a groove at each end of the blocks, for facilitating the lifting and setting of them. The contents of each cylinder were beaten down by two men, an operation which occupied half a day for each block. The moulds were allowed to remain for at least three days, before the cases were removed; but the blocks were not considered to have attained sufficient solidity and hardness, for those that were to be thrown promiscuously into the sea, until after a lapse of three months, and for those that were to be employed in forming the foundations of the piers and quays until after a period of six months. The blocks attained, in course of time, a hardness almost equal to that of stone; those first used about sixteen years back being very little worn by the action of the waves. The cost of the blocks was 12*s.* 8*d.* per cubic metre, or, including setting and other incidental expenses, 15*s.* 10*d.* per cubic metre. The entire cost of the breakwater had amounted to from £290 to £310 per lineal metre.

In the construction of the quay-walls of the docks Lazaret, Arene, and Napoleon, the system of building on artificial blocks, somewhat similar to the inside of the pier, was adopted. At 6 metres under the level of low water, an embankment was formed of second and third class stones, having a base of from 8 to 9 metres in width, and an inclination at the sides of 1 to 2. Upon this embankment, and up to the level of the water, four rows of artificial blocks were placed longitudinally side by side, making a total height of 6 metres, with a width on the top of 3·4 metres. Two rows of blocks were usually placed on these to consolidate the embankment, and were allowed to remain for about six months. When they were removed, a masonry wall was built up to the level of the quay. At the back of this wall there were other artificial blocks, from the upper side of which a further embankment of stones was formed, having an inclination of 1 to 2. The quays of the Arene and Napoleon docks were 2·4 metres, and those of the Lazaret dock 3·4 metres, above the water-line. In several places the embankment beneath the artificial blocks had moved, generally slipping forward, and causing the artificial blocks, as well as the quay-walls resting on them, to incline over towards the dock. This usually arose from an insufficient time havbeen allowed for consolidation, and most frequently occurred in the quays or the moles, where it had caused some of the walls to yield. Owing to the instability of the quay-walls, and from the nature of the embankment behind them, the quay-cranes simply rested on platforms of heavy timbers, which had sufficient base to insure stability during the "slewing" of the jibs. The entire length of the quays at present constructed, belonging to the Dock Company, was 2840 metres. The cost of the quays above the embankment, that was, of the quay-walls with the artificial blocks supporting them, was £24 per lineal metre.

Sheds, 14 and 10 metres in width, extended completely round the dock du Lazaret. These sheds were covered with a simple roofing of double T iron, the rafters for supporting the tiles being also of iron, of an A section. The side towards the dock was closed by sliding or rolling doors of corrugated zinc, the roof resting on this side on cast-iron hollow columns, and on the other on the walls of the magazines. These magazines were of one story only at present, and were constructed of rubble masonry, with dressed piers and quoins, and wrought-iron roofing, with vaults in brickwork. The amount of covered space, including the floors, was 67,132 square metres. The flooring for all the magazines and sheds was composed of a layer of asphalte ½ an inch in thickness, costing 2 francs per square metre; but including the levelling of the ground, and the bed of cement below, the cost was about 6 francs per square metre.

The bonded warehouses, or "entrepôt commercial," formed one block of buildings, to which were attached the company's offices. Two lines of railway, and a public thoroughfare which ran parallel to it, separated these buildings from the Dock du Lazaret. On the east side were sidings from the Paris, Lyons, and Mediterranean Railway, a junction with this line having been made by means of an incline and a tunnel under the town. The length of these warehouses was 365 metres (1200 feet), with a breadth of 37·5 metres, and a height of 35·7 metres. The offices were of the same breadth, with a length of 37·6 metres. The warehouses were divided into four quarters, each containing an interior court with two doorways. There were six stories above the ground-floor, with vaults below; the whole having been constructed in stone and iron, the concession requiring that all the materials should be fireproof. The masonry was for the most part a better class of irregular rubble; but the piers, arches, quoins, windows and ornamental work, were of dressed ashlar. The cost of the several kinds of masonry and brickwork per cubic metre was, hard limestone dressed and built in place, £4; less hard quality, £3 4s.; soft calcareous stone from Miramas, £2 2s.; rubble, 12s. 6d.; and brickwork, whether of solid or of hollow bricks, £2 8s. The thickness of the walls was 1·25 metre at the foundations, 1·08 metre at the ground-floor, and diminished gradually to 0·58 metre at the sixth story. The ground-floor was supported by massive stone pillars and vaulting, while the other floors rested on cast-iron columns. Each quarter was provided with two hydraulic hoists, capable of lifting 1½ ton each, and with two sets of lowering apparatus, the cradle going up empty, by means of a counter-weight, while the extra charge brought it down again. All these warehouses were constructed without the aid of scaffolding, by means of three travelling cranes, two on one side, and one on the other, of the buildings. These cranes consisted simply of a jib, 28 metres in length, suspended a little below its centre; the extreme load lifted at one time was 2½ tons, and per day, by each crane, 150 tons. There were 14,136 cubic metres of masonry in these warehouses, and it had cost 3,000,000 francs (£120,000) exclusive of the foundations, the latter having cost 203,000 (francs. All the doors and window frames were of wrought-iron, £30 per ton having been paid for the former, or in all, for the doors alone, £4800.

The floors for each story were composed of wrought-iron double T girders ¼ a metre in depth, 4·53 metres in length, and weighing 145 kilos per metre. These rested on cast-iron hollow columns varying in section at each story, according to the load. The junction of two columns with the wrought-iron girders was made in such a way as to allow of the expansion of the girders taking place. One column simply rested on the top of the other, the two ends being turned in a lathe, while the girders rested on the lower flanges of the upper column, the attachment being by bolts. The columns were all cast vertical, were 4 metres in height, and were tested to support a vertical load equal to 8 kilos per millimetre of section. The wrought-iron girders were subjected to a tensional force equal to 12 kilos per millimetre of section. The cost per ton of the girders had been £22, of the tie-rods and other pieces of wrought-iron, 500 francs, of the columns and pedestals, 300 francs, and of ordinary castings, 270 francs. The vaulting between the girders was built of hollow bricks 6 inches deep, costing 10 francs per square metre complete. The floors were all constructed to carry 2 tons per square metre, but it was believed that they would bear much more with safety.

The wrought-iron roofing of the warehouses was then described in detail. The girders were composed of two angle irons at the top, and two at the bottom of the section, separated by strips of flat iron, forming a sort of lattice web. The girders were free to move in the direction of their length, resting simply on a cast-iron shoe embedded in the wall. They were 4 metres apart from centre to centre, and were separated at the crown by similar girders. The tiles were supported by iron of an A section, 8 centimetres in depth, and galvanised. It was calculated that this roof would sustain 4 cwt. per square metre. The vaulting between the girders was of hollow bricks, similar to those used for the floors, but much lighter. The vaulting cost, including all expenses, 6s 8d. per square metre. The quantity of cast and wrought-iron was 349 tons, and its mean cost had been £24 per ton. The total cost of these bonded warehouses, comprising machinery, hydraulic pipes, &c., had been half a million of pounds sterling.

The author then proceeded to allude to the graving dock accommodation at Marseilles, which was at present almost entirely of a provisional character, a canal of communication between the old and the new ports having been temporarily converted into two docks for this purpose at a cost of £31,200; the number of ships annually docked in these two docks was one hundred and sixty.

There was likewise a floating dry dock, built of wood, about eighteen years back. It was simply a box, 64 metres in length by 19 metres in breadth, and 7 metres in depth, and cost, with engines, &c., complete, 356,000 francs. No rot whatever had as yet appeared in the timber, nor had the worm attacked it.

New graving docks were in course of construction at the northernmost extremity of the docks, leading out of the dock Imperiale. These would comprise two basins, with a hydraulic lift, on Mr. Edwin Clark's system, and a suitable shallow basin for the pontoons forming part of this system.

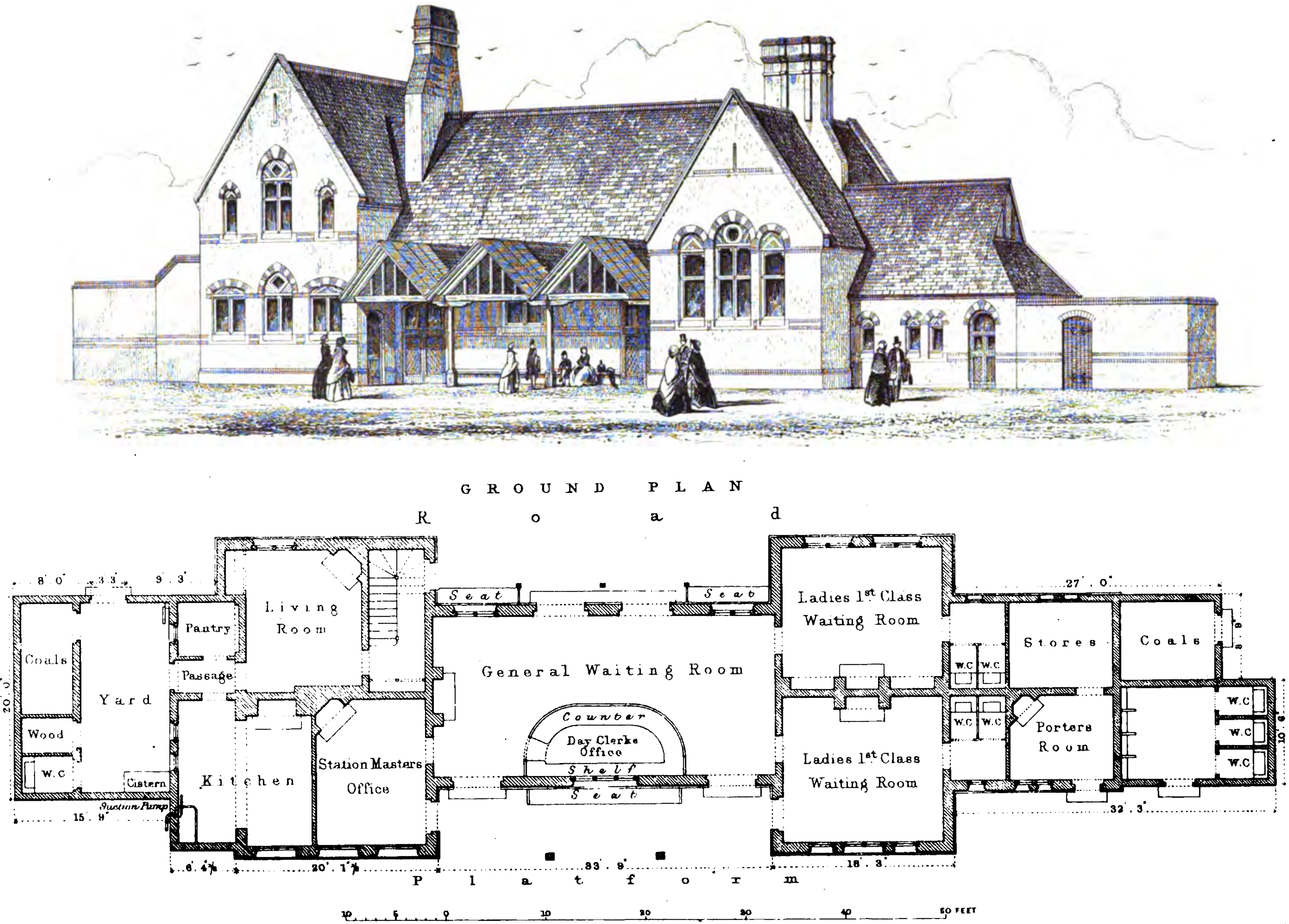
In conclusion, the author gave the results of some experiments, made by M. Barret, the engineer-in-chief, on the hydraulic machinery, with a view of ascertaining first, the volume of water actually given out by the hydraulic pumps as compared with the interior volumes of these pumps, or the working capacity at different speeds of engine; and secondly, the useful mechanical effect of the hydraulic apparatus as compared with the steam engine and accumulator. It should be stated, that the character of this machinery was precisely similar to that which had been so largely applied by Sir William Armstrong in England, and that all the designs were furnished by him, the execution of the work having been intrusted to the Société des Forges et Chantiers. The particulars of the experiments were recorded in great detail, from which it would appear that the weight lifted by the hydraulic hoists was only about 45 per cent. of the power contained in the water, and 30 per cent. of the indicated horse-power on the steam piston. This would seem to be a small result; yet where many machines were used, there was no doubt of the great advantage of this system, only one steam engine being employed, and this collecting its force, by means of accumulators, for a moment when many machines might be working simultaneously. The results of experiments with a three-cylinder direct-acting rotary engine of 8 horse-power were much greater, the useful mechanical effect being 65 per cent. of the water used, or 20 per cent. more than in the case of the hoists.

Although, up to the present time, the docks had not been successful in a commercial point of view, yet it was believed they could not fail ultimately to reap great profits, as well from the superior accommodation they afforded, as from the fact of the fast increasing commerce of Marseilles, the imports and exports to which might now be estimated at 3 million tons per annum.

BROADSTAIRS STATION, KENT COAST RAILWAY.

(*With an Engraving.*)

The accompanying plate illustrates one of the Stations on the new Kent Coast line, now incorporated with the London, Chatham, and Dover Railway. This branch is now open to Ramsgate, and has proved a great boon to the residents of the much-frequented watering-places in that neighbourhood. The station we illustrate is that at Broadstairs, and we have no doubt that, as this place is thus brought into immediate connection with the Metropolis, it will soon become as great a favourite with the public as the sister towns of Margate and Ramsgate. The line was constructed under the superintendence of Mr. F. T. Turner, C.E.; and this station affords a very fair example of those lately executed on this branch, at Margate, Herne Bay, and Birchington, from the designs of Mr. John Newton, of Salisbury-street, Adelphi, London.



BROADSTAIRS STATION, KENT COAST RAILWAY.

UPON THE SUPPLY OF WATER TO TOWNS.*

By Baldwin Latham, C.E.

Quality of River Water.—The quality of river water varies immensely with the character of the district drained, and some river waters, after being freed from the adventitious mechanical matters present, are of great purity, such for instance as the waters of some of the rivers of Switzerland, Scotland, Wales, and the north of this country. It has been already mentioned that the quality of river water is a mean between the waters of many sources; thus, the nearer the water-supply is taken to the rise or head, the purer and freer it will be from organic impurities. Rivers taking considerable supplies from permeable districts, into which the rainfall percolates the strata to various depths before arriving at the river, will contain a larger amount of inorganic matter than rivers deriving their supply from the surface drainage of impermeable districts. River water, as a rule, contains a large amount of organic matter, consisting of minute animal and vegetable organism, as well as of the matter acquired from the decay of vegetation, and from the surface of cultivated lands, and in many instances from the reprehensible plan of turning the sewage of the towns situated upon its banks into the stream. There can be no doubt that a marked improvement would take place in the quality of many rivers if compulsory powers could be enforced to prohibit the obnoxious contents of sewers and cesspools being turned into the rivers, which under other circumstances, if properly applied, can be profitably utilised.

River water, taken at points removed from the centre of great populations, or from highly cultivated lands, is often very good in quality, and being generally well aerated, is highly esteemed; the great drawback to the use of it is the variableness of its quality and temperature. These matters, together with the various modes of purifying river water, will be considered hereafter; but the following table gives a list of the impurities present, and the analysis of the water of some rivers:—

Analysis of River Water.

Name of river, and authority.	Carbonate of lime.	Sulphate of lime.	Carbonate of magnesia.	Sulphate of magnesia.	Chloride of magnesia.	Sulphate of soda.	Carbonate of soda.	Chloride of sodium.	Sulphate of potassa.	Nitrate of potassa.	Nitrate of soda.	Nitrate of magnesia.	Phosphates, earthy.	Alumina.	Oxide of iron.	Silicic acid.	Organic matter.	Total.
Clyde—Penny ...	2·52	·26	·72	...	·40	1·94	...	·54	1·94	...	...	...	·31	·28	Trace	·28	·89	7·86
Severn—do. ...	·50	·52	...	...	·66	·39	...	·73	·39	...	...	...	·18	·32	...	·32	·45	8·75
Seine—Deville ..	11·609	1·886	·189	Trace	...	...	...	·862	·35	...	·659	·364	...	·035	·175	1·711	...	17·84
Rhine—do. ...	9·511	1·03	·350	...	...	·946	...	·14	...	2·66	...	...	...	·175	·406	3·428	...	16·247
Garonne—do. ...	4·524	...	·238	...	...	·371	4·55	·224	·533	...	...	..	...	...	·217	2·813	...	9·585
Loire—do. ...	3·374	...	·427	...	...	·288	1·423	·336	...	...	...	...	...	·498	·385	2 848	...	9·437
Rhone—do. ...	5·834	...	3·43	...	...	·519	...	·119	...	·28	·315	...	·333	...	...	1·669	...	9·082
Doubs—do. ...	13·397	...	·161	...	·035	·357	...	·161	...	·287	·273	...	...	·147	·21	1·114	...	16·142
Thames—Letheby	11·10	4·78	...	...	...	·48	...	1·88	...	...	...	...	...	·76		1·0	2·75	22·75
Ouse (Ely)—do. ...	13·0	10·39	...	...	·37	1·01	...	2·50	...	3·40		...	...	·67		·12	1·34	32·8
Lea	...	...	...	...	...	...	...	...	...	..		...	...	...		...	...	23·7
Colne	...	...	...	...	...	...	...	...	...	...		...	...	...		...	...	21·3
Trent	·32	21·55	5·66	...	...	...	...	17·63	...	...		...	Trace	·50		·72	3·68	50·16
Dee	·85	·12	·36	...	...	...	...	·72	...	...		...	Trace	·06		·14	1·64	3·89
Don	2·23	·13	1·07	...	...	...	...	1·26	...	...		...	Trace	·27		·52	3·06	8·54

The following is a list of some of the towns of this country that derive their water-supply from rivers and streams:—

Name of town.	Quantity of water used daily.	Name of river or stream.
Banbury	120000 gallons	River Cherwell
Barnstaple	120000 ,,	A brook
Carlisle	1000000 ,,	River Eden
Chester	900000 ,,	River Dee
Dublin	12000000 ,,	River Vartry
Durham	350000 ,,	River Weir
Ely	300000 ,,	River Ouse
Exeter	960000 ,,	River Exe
Hereford	220000 ,,	River Wye
Ilfracombe	30000 ,,	A stream
Leamington	300000 ,,	River Leane
Leek	200000 ,,	A stream
Lynn	1000000 ,,	Ditto
Middlesbro' and others		River Tees above Darlington
Newark	150000 ,,	River Trent
Penrith	300000 ,,	River Eamont
Perth	250006 ,,	River Tay
Southampton	1800000 ,,	Partly from river
St. Thomas the Apostle	90000 ,,	River Exe
Stockton	...	River Tees
Torquay	360000 ,,	Dartmoor
Wakefield	400000 ,,	River Aire
Wellington	...	Wrekin Brook
Wolverhampton	1250000 ,,	River Worf
York	1306000 ,,	River Ouse

Supply from Natural Springs.—It has been already observed, that many rivers receive a portion of their supply of water from springs; consequently, those towns which use the water of rivers are literally deriving a supply partly from springs and partly direct from drainage areas; for the permanent flow of a river is due to its receiving large accessions of water from springs. It may sometimes occur in practice that a spring itself may be taken advantage of to furnish a supply of water; or if the natural flow of water from such spring is insufficient of itself, yet, as it may indicate the source of a more copious supply, no paper on water-supply would be complete without an inquiry into the theory of springs.

It has been shown that the amount of rain falling on elevated localities is more than on low table-land; the flow of water from springs is due to the rainfall that has been absorbed by the porous strata of the highlands of a district into which it percolates, until intercepted by some impervious bed of strata, by which it is retained in the porous strata, and compelled to traverse it in the direction of its inclination, until at length it may make its appearance at the surface of the ground, at a point somewhat lower than that at which the meteoric water was received. The power that impels the rain through the porous strata is hydrostatic pressure, which in some measure is modified by the friction and the capillary attraction of the strata through which the water flows. Springs are kept constantly flowing by the repeated rainfalls and the modifying influences of the strata already mentioned. The permanency of a spring is consequently closely allied to the character and extent of the strata through which the water may flow. If the strata is of an open or porous character, and of but small extent, the springs flowing from it will vary much in their delivery, and will, in all probability, become intermittent in their flow. If, on the other hand, the strata is moderately porous, and of large extent, springs yielded by it will generally be large and permanent. Of such may be said to be the springs flowing from the chalk or greensand formations. Springs may be divided into classes, each class depending upon the relative position of the strata with respect to the discharge of the water, and acquirement of the meteoric water

* Continued from p. 24.

The first class may be called land springs, and are found in those places where a superficial strata (as sand or gravel) of moderate thickness covers an impermeable strata; and a natural flow of water will take place if there is a dip in the strata, and at the lower outcrop springs of this nature will appear, but owing to the limited area of the strata they are generally of an intermittent character, as they depend directly upon the rainfall to keep up the flow. Closely allied to this class is another, consisting of porous strata of great extent and depth, from which the water flows as in the preceding case. Of this class may be said to be the chalk springs in some districts, and which, owing to the great extent of their area, act as immense reservoirs to store the water, which is pretty uniformly liberated, owing to the friction of the water in passing through the strata, and the attraction the strata itself exerts, which retards the speedy escape of the water. Another class of springs may be described as those flowing from a porous strata. Lying between beds of a more impermeable character, springs of this class make their appearance at the outcrop, or through any fault in the open impermeable strata; but inasmuch as they receive their supply of water only at the basset of the strata, which is generally of a limited area, springs of this description cannot often be depended upon to furnish a large or permanent supply of water. Another description of spring may occur by reason of a fault or intervention of an impervious dyke when a permeable strata overlies an impermeable. The volume of water yielded by springs of this nature is often great, owing to the interception of the body of water flowing through the stratum. The constancy of a spring depends upon the extent and character of the strata, combined with the rainfall. The flow of springs that are intermittent has been shown to arise from the limited extent and the porosity of the strata. The flow from springs may also fluctuate owing to the formation of the porous strata; thus, if the porous strata is so disposed as to constitute a reservoir, with a sort of syphon arrangement for its discharge, the action of such spring will be intermittent. The limpidity of water flowing from springs, and the elevation at which they are often found, renders them, under certain circumstances, extremely valuable in furnishing supplies of water, and they have been made available, in many instances, for the supply of water to many towns, both in this and other countries.

London, prior to the construction of the waterworks at London-bridge, near the end of the 16th century, was partly supplied by springs, which were conveyed into the city by lead and earthenware pipes, principally at the cost of different lord mayors, and the munificence of some wealthy citizens.

The gigantic scheme of supplying London with water from the springs at Chadwell and Amwell, which, by the instrumentality of the New River Company, was realised on the 29th of September, 1613, forms a striking example of the utility and copiousness of some springs for furnishing a supply of water to towns.

But not only have springs been made available in this country, but also in others; and, at periods in history far more remote than we can boast of in this country, have works of magnitude been constructed for conveying the water from distant sources into numerous cities and towns.

Spring water has the advantage of issuing from the earth at nearly always the same temperature, and on this account is commendable. In making calculations for the supply of water from springs, it should be borne in mind that the volume should always exceed the maximum demand, and if the springs are of such a character as to fluctuate in their flow, so that the entire yield may be sufficient, or in excess of the entire consumption or demand, it may be advisable, if not absolutely necessary, to store the excess of water in impounding reservoirs for use during the periods of limited supply, in which case the quantity to be stored will depend upon the rate of fluctuation of the flow.

Quality of Spring Water.—The quality of spring water varies considerably, but as a rule, the quicker a spring is affected by the rainfall (all other circumstances being equal) the purer will that spring be. The water furnished by land springs is generally of an impure character, as it is contaminated by the impurities of the surface, which are to some extent mineralised in passing through the strata.

All spring water contains more or less mineral matters, which they acquire during the process of infiltration through the pores of the strata. A very small quantity of this exists in mechanical suspension, being chiefly held in solution by the action of chemical agencies. The principal agents that render the strata so readily soluble are the acids and alkalies, which combine with the ingredients composing the strata of the earth, and form compounds readily soluble in the percolating water. The value of spring water for domestic purposes depends upon its freedom from the compounds of earthy salts, and from organic matter; and in making choice of a supply, if the springs of a locality are found to contain a much larger percentage of foreign matter than a source that may be made available at a somewhat greater cost in the construction or working expenses, it may be economy to abandon the near spring for another source. This selection of the source often furnishes a nice point for the engineer to decide; yet there are certain well-defined points bearing upon the quality of water procured from various sources that will be considered hereafter, which should be the guide of the engineer in making his selection.

Wells.—The art of well-sinking is common to all countries, and was probably one of the earliest artificial means adopted to furnish a supply of water. From the earliest periods of history the records of both sacred and secular writ go to prove that the art was pursued alike by the savage who roamed the desert, and the citizen who inhabited the town; yet it should be here observed that there is a marked difference between the mere hole the savage may scratch in the sand, and the highly-finished wells of some Eastern cities. So ancient are wells, that Ewbank observes they must have been of antediluvian origin; and that such useful works remain long after the destruction of those more splendid edifices that have been erected more for the glory than the usefulness of mankind. The buried cities of Nineveh, Herculaneum, and Pompeii, abound in wells of excellent construction, containing good water, and which at the present day supply the inhabitants living in those localities. It is probable that the first wells were shallow holes excavated in the loose soil in moist places, such as are found at the present day to be executed by uncultivated or uncivilised nations or tribes. After the discovery of the metals, which is supposed to have taken place in the seventh generation, as Ewbank observes, rock and indurated strata no longer offered an impediment to the well-sinker, and, consequently, wells were sunk to greater depth in such strata. As the art of well-sinking developed itself at an extremely early period, and long anterior to the commencement of history, no very great advance has been made in it; indeed, the mode usually adopted at the present day when sinking wells to a great depth in loose strata, by first forming a curb on which the ordinary steining is placed, and which settles down as the work of excavation is carried on within, and thereby preventing the loose soil falling into the well, was practised ages ago in sinking wells in the East, and from them we have copied the mode in more modern times. Wells of excellent construction abound in Hindostan, China, Japan, Tartary, Egypt, and elsewhere. When the British took possession of Hindostan, the number of wells in use in that country was estimated at 50,000. Many of the ancient wells were of great depth. The wells of Cabaul are from 300 feet to 350 feet deep, and many of them are but 3 feet in diameter. The famous well at Tyre is said to be 630 fathoms in depth. Jacob's well at Samaria is 105 feet deep and 9 feet diameter. The well Zem-Zem, at Mecca, is 210 feet deep, and that of Joseph, at Cairo, 300 feet deep. This well of Joseph is a fine example of the skill and boldness of design of the well-sinker. Although called after Joseph by the Arabs, it is by no means of so ancient a date as the name would imply, for the well was probably sunk about seven hundred or eight hundred years ago, but by whom is a disputed point; some attributing it to a vizier of the name of Joseph, others to Saladin, the intrepid defender of his country, whose name was Yussef (Joseph). The well consists of two shafts, one above the other, but not in the same vertical line. The upper shaft is an oblong excavation 24 feet by 18 feet, and 165 feet deep, descending into a large and capacious chamber, in the floor of which is constructed a basin or reservoir for containing water that is raised from the lower shaft. In this chamber a lower shaft is sunk, which is an excavation 15 feet by 9 feet, and 130 feet deep. Round the upper shaft, a spiral passage 6 ft. 4 in. wide, and 7 ft. 2 in. high, is cut, separated from the well by a partition wall of the solid rock, only 6 inches in thickness, through which loopholes are pierced for lighting the passage. This passage is made use of by parties who draw water, and also for the descent of mules or other animals that are employed in the large chamber below, to give motion to a system of chain pots by which the water is raised from the lower shaft and poured into the basin in the chamber. There is also a spiral passage round the lower shaft, but it is not inclosed from the well, as in the case of the passage round the upper shaft. The water of this well is procured from a bed of gravel, after penetrating the strata to the depth before-mentioned. Wells are common in Greece, and in the olden times of its classic glory were the places of public resort; just as in modern times men congregate at their clubs and such like places, so did the sage Athenians meet together at their wells, and at them orators declaimed, and music and the dance lent their charm to make them places of pleasure and amusement.

The Romans had a clear knowledge of the art of well-sinking, and wells executed by this people are found in every country they once possessed. Many of the successes of their arms were due to their knowledge in this branch of engineering, as, when every other source of water failed, or was cut away by their enemies, they had recourse to well-sinking to obtain their supply. It was the knowledge of well-sinking that enabled Cæsar to retain Alexandria when all the water of the cisterns had been spoiled by the Egyptians. The same knowledge enabled Pompey to procure a supply of water when holding a position of great advantage against Mithridates, who had abandoned it for want of water. Imperial Rome (prior to the time of Appius Claudius) was supplied with water principally from wells.

The water procured from wells is rain that has descended by the minute interstices of the earth's crust, and is stored in the numberless interstical spaces of a porous strata.

Wells may be classified under two heads—viz., Ordinary Wells, or those sunk into permeable or water-bearing strata; and Artesian Wells, or those sunk, or more generally bored, through impermeable strata until a water-bearing strata is tapped, when the water is forced upwards by virtue of the hydrostatic pressure due to the superior level at which the meteoric water was received.

Ordinary Wells may be again classed under the respective heads of Shallow and Deep Wells. The water from both classes is procured under precisely the same circumstances, but differs often very materially in quality and quantity

Shallow Wells include ordinary domestic wells sunk a few feet into the permeable strata of the earth's crust, and, owing to their shallowness generally, only catch the adjacent percolating water, consequently cannot be depended upon to give a large supply; and inasmuch as they are generally contaminated with the contents of sewers and cesspools when sunk in the superficial deposits under cities and towns, which are honeycombed with such offensive receptacles, or tunnelled with imperfect and leaky sewers, their waters are not to be recommended for general use.

Deep Wells sunk into permeable and water-bearing strata derive their supply from a more remote and extensive drainage area brought into action by the depth given to the wells; and the quantity yielded by them is limited by the friction of the water in passing through the interstical space and the molecular attraction of the strata for retaining the water, which practically limits the area drainage into the well.

Astesian Wells have ages ago been in use, and the antiquity of boring wells of this class is so great that the precise period of their introduction is unknown. They are common to Syria and Egypt. China abounds with them, many being upwards of 1800 feet deep, and but 6 inches diameter. They are common in Italy and France; and in the province of Artois, of the latter country, they are so abundant that one may be found at nearly every door; and it is from this province that the art of sinking or boring such wells came into this country, and they are named by us after that place. Artesian wells are artificial springs, and the same remarks that apply to deep-seated springs will apply to Artesian wells.

The quantity of water yielded by wells cannot be absolutely computed, as it is dependent upon so many varying circumstances; but in considering this part of the question we must have regard to the area of drainage, the nature of the stratum, its dip, strike, faults, absorbent properties, and the nature of the underlying and overlying strata, the rainfall, and the depth of the well itself.

The theory of the probable quantity of water yielded by wells is called the cone theory; *i.e.*, the drainage area contributing to the supply of a well is represented by an inverted cone, the apex of which is at the bottom of the well, so that if the strata were perfectly uniform, and the flow through it equable, the quantity yielded by wells sunk to various depths would be represented by the area of the different cones; but inasmuch as perfectly uniform strata of any great extent is rarely met with in nature, it is impossible to lay down any but general laws in studying the probable yield of water by wells.

Physical Properties of the Strata.—The yield of water from a well depends upon the nature of the strata; thus, if the strata is of a close texture, having but few and small interstical spaces, the drainage area is limited by the friction of the water in flowing through it, and by its capillary attraction; consequently, in strata of this character the area contributing to the supply of a well will be represented by an inverted cone of acute irregularity; while on the other hand, if the strata has large and numerous interstical spaces, it will yield water rapidly, and the area contributing to supply such well become practically infinite. And just in proportion as strata approach one or other of the descriptions of the strata mentioned (all other things being equal) so will the supply of water capable of being procured from wells sunk into them vary. The construction of a well will also influence the flow of water, as for instance, when a well is sunk into dense but permeable strata containing much water, naturally yielding it slowly owing to the fineness of the interstices, by special arrangement an increased supply could be procured; these arrangements consist generally of long tunnels or headings, driven or extending horizontally, sometimes to great distances of the shaft. They have the double advantage of not only offering a greater surface to allow of the escape of water into the well, but they also act as reservoirs for storing it, which is a great advantage in all cases, but more especially when the water is required at intervals, and not continuously. The nature, character, and position of the water-bearing strata, from which wells derive their supplies, must be carefully considered by every person who desires success to crown his labours in practising the art of well-sinking. It has been already shown, under the head of Absorption, that the quantity of water sinking deep into the ground is influenced by many circumstances, and is not alone dependent upon the character of the strata; yet it is quite obvious to the most casual observer, that the nature of the strata has the most important bearing upon the quantity and quality of water yielded by wells; thus chalk, from its absorbent nature, has been found, by observation on the steep chalk hills around London, to absorb a rainfall of 2 inches per hour; the red sandstone formation, under suitable circumstances, also absorbs rainfall very rapidly, while the more impervious strata absorbs it but slowly. The dip or strike of the strata will also have an important bearing upon the amount of water yielded by a well, as it may occur that the natural inclination of the strata may be unfavourable to the yield of any great quantity of water in a particular locality.

Faults have a material influence upon the flow of water in the subterranean passages of the earth, and, consequently, have much to do with the amount of water capable of being yielded by wells. The level of the water in the same strata when disjointed by a fault is no longer the same, but may vary considerably; and it may also often happen that a well may turn out to be a failure owing to the near proximity of a fault, cutting off and diminishing the drainage area. The careful study of the strata should always form an important point in considering the desirability of well sinking, and the want of such study often entails failures, which we ascribe to faults; but the probability is, that with further insight and clearer knowledge, many of these failures (which are rather the fault of the engineer, than any fault in nature) would not arise. Water flowing in the bowels of the earth follows the same laws as water flowing on the surface of the earth, except when modified by some disturbing cause. The line of saturation, or the level at which water may be procured, varies in different strata, and is affected by various causes; thus the effect of continuous pumping in a district is to lower the water level of such districts. Generally the water level in strata has an inclination in the direction of its flow; thus it has been established, by the Rev. Mr. Clutterbuck and others, that the inclination of the line of saturation in the chalk in the north of London is 13 feet per mile. In other places it varies according to circumstances; thus, it is not improbable that the flow of some intermittent springs is due to the elevation in the line of saturation, as in the bourne at Croydon, which breaks out occasionally after very heavy and continuous rains. As a rule it will be found that in those districts in which the flow of water from springs, and the flow of rivers, is equable, or neither subject to excessive floods or droughts, but is always discharging a quantity very near the mean flow, so will it be found that wells sunk into the particular strata from which these rivers or springs derive their principal supplies will yield the greatest quantity of water.

Quality of Well Water.—The character of well water is fixed by the geological strata through which it flows—for as the water is making its way through the bowels of the earth, sometimes travelling a considerable distance, it dissolves more or less of the materiais of the crust of the earth in its passage, and becomes impregnated with the soluble portions; on this account, well waters are never perfectly free from foreign substances, volatile or solid, which impress upon the water its character. The water of shallow wells of towns is invariably impure, owing to the infiltration of decomposing matters, which to some extent may become oxidised and decomposed in passing through the soil, and the gases evolved, after further oxidation, combine with the materials it comes in contact with in its passage; which, being rendered soluble by this means, add greatly to the impurities present in the water. Thus the shallow wells of towns invariably contain a large quantity of nitrates in solution; they also often contain organic matter in the shape of animalculæ and fungi, the presence of which, if not directly injurious, is indicative of the presence of other matters, highly objectionable, if not prejudicial. Although the soil has great power in oxidising the most objectionable matters before they enter the wells, it is by no means certain that the earth can retain this power for any length of time, especially as the sources of contamination are multiplied; indeed, there is ample evidence to show that this power of the soil is limited; as for instance, the cases mentioned by Sir James MacGregor, who relates that when the British army was in Spain 20,000 soldiers were buried in a short space of time, in rather a small piece of ground, and the effect upon the adjacent wells was such, that the troops who made use of the water of those wells were attacked with malignant fevers and dysentery. The water of deep wells is generally freer from organic matters than that of shallow wells, but it generally contains an amount of mineral matter. The water of deep wells, on account of their freedom from organic matters, are generally very agreeable as drinking water, if of proper temperature, but for some purposes they are objectionable on account of their hardness.

Composition of Well Waters.

	London shallow wells.	Ely upper part of city.	Ely lower part of city.	Burton on Trent.	Croydon.	Braintree.
Carbonate of lime	30·50	25·10	37·50	15·51	15·41	2·40
Carbonate of magnesia ...				1·70	·61	11·30
Sulphate of lime	8·20	18·36	52·34	18·96	·53	
Sulphate of magnesia ...				9·95		·70
Chloride of magnesia ...		·18	2·61			
Chloride of sodium	12·30	10·88	44·90	10·12	1·51	44·00
Alkaline sulphates	14·70	16·97	24·37	7·65	1·03	
Alkaline nitrates	16 70	28·88	36·86			12·80
Iron alumina	1·10	·71	·84	·60		Traces
Silica...		·14	·13	·79	·93	1·30
Organic matters		·68	·53		1·09	
Total	83·50	101·90	200·08	65·28	21·11	72·50

Temperature of Well Water.—The temperature of water taken from the bowels of the earth is somewhat higher than that of waters found upon the earth's surface. The rate of increase has been variously estimated: thus, Mr. Paterson, in a magazine published in 1839, states that the mean temperature increases, in the scae of eleven wells sunk in Scotland, about one degree Fahrenheit for every 48 feet descent. M. Valferdin found that in some wells in Paris the rate of increase was one degree for every 57 feet descent. M. de Girardin found at Rouen that the rate of increase was one degree for every 37½ feet of descent, and in another case one degree for every 55½ feet descent; while careful experiments on the Artesian well at Grenelle give an increase of one degree for every 59 feet descent. The mean temperature taken from the above observations would give a mean result, showing that the rate of increase of temperature as we descend is one degree Fahrenheit for every 52 feet descent. Owing to this rate of increase in the temperature of water taken from deep wells, when the well is very deep and the increase in temperature very great, the water is totally unfit for many purposes, and this fact should be taken into consideration when deciding on a source of supply. The temperature of the water at the well of Grenelle, which is nearly 1800 feet deep, is 18·81 deg. Hospitals and public baths have been heated with this water.

Form of Wells.—Various forms of wells have been made at different times, and under varying circumstances, and in all ages. The square, oblong, ellipse, and circle have all been used with success. Such of the wells of the east as were executed in solid rock and without steining, are sometimes in the form of a square, sometimes oblong (as Joseph's well), and sometimes circular, but of all the forms the circle is the best. The ellipse can be used in some special cases with advantage, but for all practical purposes the circle is by far superior to any other form, as a well of this form can be bored or misered to great depth under water. It requires less steining than any other form or shape of well of equal area, and its form is the best for withstanding the lateral pressure of the earth, as a strain on a particular part is mutually sustained by the whole steining.

Materials used in the Construction of Wells.—The sides of wells require lining or steining (as it is termed) with some material that can prevent the loose strata of the sides of the excavation falling into the well and choking it. The materials that have been successfully used in this work are brick, stone, timber, and iron. Each description of material is suitable under certain conditions, while in other positions it is objectionable. Brickwork, which is universally used in steining wells in this country, not unfrequently fails in certain positions; as by reason of admitting mpure water under great pressure, or from the work becoming disjointed from settlement due to the drainage of a running sand-bed and the collapse of the well. Stone of good quality, capable of withstanding compressive strains, is good in its way; but inasmuch as it requires an immense amount of labour to fit it for its place, it cannot successfully compete with brickwork in the formation of wells, more especially as it has no merits superior to those of brick when used in such work; however, if in any locality, by reason of its cheapness, it can be used, care should be taken to select only such samples as contain a large amount of silica; indeed, in all cases it is a point of great importance in studying the nature of the materials used in the construction of wells, to select those which are likely to be the most durable, and at the same time preserve the purity of the water contained in the well; and this is best secured by siliceous materials. Timber is objectionable as a material to be used in the formation of wells, on account of its liability to decay, and thus not only endanger the construction of the well, but likewise to some extent foul the water by such decay. It is very largely used under some circumstances, especially in the preliminary operations in sinking most wells. It is also successfully used in lining the shafts of the salt wells of Cheshire, and will continue entire in such position for a great number of years, as the brine seems to have a tendency to preserve the timber, and prevent its decay. Iron is of modern application, and is a material extensively employed in steining wells; and as it possesses many advantages over materials ordinarily used, its use is likely to be much extended. It possesses all the qualities of a good material, insomuch as by its character it is capable of bearing great compressive strains, and of effectually excluding the influx of all such waters as it may be desirable to keep out, and is not liable to decay under ordinary circumstances. The author has known instances where recourse has had to be made to the use of iron cylinders, where it has been found that four or five rings of brickwork, set in the best cement, have failed to keep out brackish waters; and if the original design had provided for the introduction of these cylinders, they would have reduced the cost of the well very materially.

The introduction of iron as a steining for wells, whether in the form of cast or wrought iron cylinders, under many circumstances, will always be attended with economy and success. The well-sinker of the present day has often, in executing his work, to contend with the presence of large volumes of water, which, under ordinary circumstances, must be got rid of by pumping; but by the introduction of iron cylinders, which can be sunk under water by the aid of the boring-tool and miser, the consequent expense of pumping is saved. It will be entirely a matter of calculation whether or not they should be used; but generally, and when no special object is required to be fulfilled, brick steining is the cheapest; though when the strata is particularly treacherons, it is decidedly the best to have recourse to iron. Iron cylinders are absolutely necessary in sinking through sand charged with water; otherwise, if there is a current of water produced, the sand flows with it into the well, which is objectionable, as the sand speedily destroys or injures the pumps—moreover, it is attended with a more serious evil, and that is, the draining of the sand undermines the superincumbent strata, which may lead to the destruction of the well itself, or any buildings erected over it. In some cases where cast-iron has been used in wells and the shafts of mines, it has been softened by the action of the water, and converted into a species of plumbago. This in itself is not any objection to the use of iron, but rather to the use of such waters that are affected by it, if used for the ordinary purposes of water supply for which the well was sunk. If, on the other hand, the action takes place from the attack of water it is desirable to keep out of the well, wrought-iron may be substituted with advantage in the place of cast-iron, or other measures may be adopted to preserve it. It may be observed that it is but in few cases that this action upon the iron can arise, and when it does, it is not in those districts that must rely upon obtaining a supply of water from wells.

Copper was one of the early materials used in lining the bore-holes of Artesian wells, but of late years iron has entirely superseded it in this branch of engineering.

Mode of sinking Wells.—In sinking ordinary wells in loose strata, an excavation is made to such a depth as the strata will admit without falling in. A wooden curb is then placed in the bottom of the excavation, and the brick steining laid upon it, and when carried up to the surface, the work of the excavation is carried on; but the way in which it is now proceeded with depends upon the method adopted in extending the steining. If the steining is intended to be added below the curb, the earth is excavated flush with the interior sides of the well, so that the earth underneath the curb supports the brickwork above. When the excavation has been carried on as far as convenient, recesses are made in the earth under the previous steining, and in these recesses the steining is carried up to the previous work. When thus supported, the intermediate portion of earth between the portions of brickwork carried up are cut away, and the steining completed. By a succession of operations of this kind the well is sunk, and the steining carried to the required depth. On the other hand, if the steining is added from above, the curbs are supported by iron rods, fitted with screws and nuts from cross timbers over the mouth of the well, and as the excavation is carried on below, brickwork is piled on above, and the weight of the steining will carry it down as the excavation proceeds, until the friction of the sides overpowers the gravitating force or weight of the steining, when it becomes, as it is technically called, earth-bound; then a set-off must be made in the well, and the same operation repeated as often as the steining becomes earth-bound, or recourse must be had to the first method of under-pinning. Brick steining is executed either in bricks laid dry, or in cement; when the work is laid dry, a ring or two of brickwork in cement is often introduced at intervals, varying from 5 feet to 12 feet apart, to strengthen the work and facilitate the construction of the well. The bricks are laid flat, breaking joint; and to keep out moderate land springs, clay, puddle, or concrete is often introduced at the back of the steining; for most purposes concrete is the best, as in addition to its impervious character, it adds greatly to the strength of the steining.

The same measures used in sinking brick steining are adopted with iron. Generally the cylinders are made of cast-iron, either cast entire or built up of several shutters; the cylinders having internal flanges, by which they are bolted together, and which add very much to their strength; they are usually secured together by bolts, and the joints are caulked with iron cement. Cylinders of this description, when they become earthbound, can be driven so that they may be sunk to considerable depths without much trouble. The cast-iron pipes used in lining the bore-holes are put together with collars sunk into a recess at the ends of the pipes or cylinders, and to which they are secured by countersunk screws, so that both the external and internal face of the cylinder is flush, and offers no impediment either to their being sunk or to the flow of water. When the supply is taken from sand, it is usual to perforate the pipes, but this is not necessary in most strata; indeed, in the bore-holes in chalk and sandstone, or other strata that will stand without artificial supports, it is not usual to line a stein, except in cases where it is desirable to shut out some particular waters.

Boring Wells.—The art of boring wells is evidently more modern than the practice of sinking, yet it is of so remote a date that the precise period of its introduction is unknown. Wells that have been bored are common in China, Syria, and Egypt; and many of them are supposed to have been executed four thousand years ago. In France, the earliest authenticated well is at Lillers, supposed to have been executed in 1126. In boring wells two systems have been adopted—one is called the Chinese system, and consists in having the boring-tool attached to a rope; the other is the ordinary method, in which the boring-tools are attached to a rod of iron or wood. Although these are the two primary ways adopted in boring, there are many modifications of them in practice combining one or other method; indeed, every engineer or contractor may have his own particular mode, or the circumstances connected with each work may demand the introduction of particular measures.

The method designated the Chinese is the simplest that is practised, as all the boring-tools are attached direct to the rope worked vertically up and down, the torsion of the rope giving sufficient rotary motion to the tool to enable it to strike a fresh spot at every descent. The facility with which the tools can be raised by the rope in this system seems at first to commend itself; but in practice, when sinking deep wells, it is open to serious objections, as owing to the flexibility of the rope the tool cannot be properly guided, and the bore-hole is likely to become crooked, which would in time interfere with the working of the tool, and in cases where the bore is to be lined with pipes would render difficult, if not prevent their insertion.

The ordinary plan adopted in boring is to attach the tools to a rod, consisting of a number of lengths joined together; a vertical and circular motion is given to the rods. In deep wells, much time is necessarily lost in raising and lowering a long length of rod, either to change the tool or bring up the *débris*. Various attempts have been made to economise the time thus spent; as for example, it has been proposed to make the tools slide upon the square boring-rods, and by attaching them by chains or ropes to a windlass when they require raising, it could be speedily done, as in the Chinese system, because it would not be necessary to unjoint the rods, as required when using the ordinary tool. Another method, patented by Beart in 1844, was to make the rod of the boring-tube hollow, and into this tube to introduce water, which, ascending outside the boring-tool, was to produce a sufficient current to carry the materials loosed by the boring-tool to the surface. A very great objection to this method (even supposing it to be practicable) is the necessity for having a large volume of water, which generally in boring cannot be easily procured until the spring is tapped.

In boring deep wells, the weight of the rod and the force of the momentum in falling is very likely to break the tools used, or the rods themselves, when special provision must be made to prevent it. This it has been attempted to do in various ways. Thus, wooden rods hooped with iron have been substituted for the iron bar; tubular iron rods have been used, having the same weight per foot as the ordinary bar, but having a greater area; when working in water they lose a considerable proportion of their weight—in fact, equal to the volume of water they displace. Both wooden and tubular rods will answer very well when the depth is not great, but when the depth is great they are not sufficient to meet the exigencies of the case. When a sliding joint was introduced by Œngalhausen, in Germany, M. Kind, in France, and in the system known as Kind's system in this country, any portion of the entire weight of the rods can be brought into action, as all those rods above the slide joint are counterbalanced by a weight suspended to a lever. In Kind's system the rods are often put in motion by a steam-engine, in the following way:—The rods are attached to one end of a lever resting on a fulcrum, the other end of the lever is attached to the piston-rod of an upright steam-engine; the valves of the cylinder are worked by a man; the rods are lifted by steam pressure, and fall by their own weight.

The tools used in boring differ according to the description of strata they are required to penetrate. Thus, when the strata is hard and compact, chisels of various descriptions are used to loosen the materials, which are either raised with an auger, or shell-pump, or miser. When the materials are of a soft nature, augers of various kinds are used. It very often happens that in deep borings it is almost impossible to escape breaking the tools used, when special instruments have to be used to raise them.

Towns supplied from Wells.—The art of well-sinking in a great measure may be said to be empirical, and it by no means follows that because water is procured in some places from wells and borings in sufficient abundance to supply a town, that water can be procured anywhere by sinking or boring, as it requires a combination of circumstances not generally met with to render the work successful; and as all theory, when applied under unknown circumstances, may lead to error, a collection of examples of wells in use at various places where water is raised for public purposes, will be highly useful in guiding us in estimating the quantities of water likely to be procured under given circumstances.

Birkenhead, Cheshire, is supplied with water from two wells 395 feet deep, partly sunk and partly bored in the new red sandstone formation. From experiments made upon one of these wells, when the water-level was 120 feet from the surface, the well yielded 1,807,461 gallons in twenty-four hours; by lowering the head another 4 feet, the well yielded 2,000,000 gallons in twenty-four hours.

Brighton, Sussex, is supplied with 1,080,000 gallons of water daily from wells sunk into the chalk.

Bury St. Edmunds, Suffolk, is partly supplied from two wells sunk in the chalk to a depth of 86 feet, and connected by headings. There are about 130 feet of heading, 6 feet × 6·5 feet, in connection with the two wells. Very accurate observations have been made upon the level of the water in these wells by Mr. John Croft, in the year 1860, and continued to the present time. Observations made by the same gentleman on a hundred wells sunk into the superficial strata of the town show that the water-level in all of these is very nearly the same, and varies in any case but a few inches. The wells upon which these observations have been made were sunk by the local authorities, not with a view of supplying the inhabitants with water, but for the purpose of procuring a supply of water for watering the roads, and other public purposes; but since the original construction of the wells a portion of the town has been supplied. The quantity of water yielded by these wells fluctuates greatly, and is dependent upon the season of the year. Thus upon one occasion, after a trial continued over seventy consecutive hours, the well yielded water at the rate of 150,000 gallons every twenty-four hours; but the ordinary quantity supplied is about 60,000 gallons per day.

Coventry, Warwickshire, is supplied with 750,000 gallons of water per day from two bore-holes made in the bottom of the reservoir, 100 feet diameter; the bore-holes are respectively 6 inches and 8 inches diameter, and 200 feet and 300 feet deep. The supply is procured from the red sandstone; and from observations made it has been found that the two yield water at the rate of 700 gallons per minute.

Croydon, Surrey, is supplied from two wells sunk into the upper chalk, one being 75 feet, and the other 150 feet deep. The latter well was sunk by Mr. Thomas Docwra, under the author's direction; and although sunk but 56 feet from the old well, it has been proved, by a series of careful experiments, that there is very little communication between the main body of the water in the two wells. Thus, when water at the rate of 1,000,000 gallons per day was being raised from each well, the relative water level in the two wells was not the same, but was 7 feet lower in the new well than in the old. By stopping the pumping operations in the new well, and continuing them in the old, the water level in the new well rose 5 feet above the water level in the old well, proving the two wells to be independent of each other. The quantity of water yielded by the old well during the last dry summer was at the rate of 1,500,000 gal. per day, and was only limited to this quantity on account of an insufficiency of steam power to raise more.

Kingston-on-Hull, East Yorkshire, was formerly supplied with river water, but during the present year the town has been supplied with water raised from a well sunk at Springhead, and forced by steam power to the old works at Stone Ferry, a distance of nearly 5 miles, from which place it is again pumped and distributed to the town. The well is sunk and bored in the chalk to a depth of 281 ft. 6 in., of which 210 feet is an 18-inch bore. The well itself is 14 feet diameter, and steined partly with iron cylinders and partly with brickwork. At the present time the well is yielding 3,500,000 gallons for the supply of the town; the water available is estimated by Mr. Thomas Dale, the engineer for the works, as not less than 4,000,000 gallons in twenty-four hours. Owing to the large influx of water, and the position of the pumps, special measures have been taken by the engineer to shut out the water from the well when an examination of the pump valves is necessary. This is effected by lowering a conical weight weighing 5 tons into the bore pipe, the bottom of the well being covered with cast metal plates secured to the sides of the well and to the bore pipe. With this plug in the bore pipe it is found that one pump will keep down the water while any repairs are required to be made to the other pump. In sinking this well it was observed that the water was obtained from the under side of the layers of flint intersecting the chalk.

Liverpool, Lancashire, is partly supplied with water from wells sunk in the new red sandstone formation. Some of these wells yield as much as 3,250,000 gallons daily.

St. Helen's New Waterworks derive their supply of water from two wells sunk in the red sandstone. Each well is 210 feet deep, exclusive of the bore, and they furnish a supply of 572,000 gallons of water daily.

Stourbridge, Worcestershire, is supplied with 150,000 gallons of water daily, from a well 6 feet diameter and 30 feet deep, sunk in the red sandstone formation.

Tranmere, Cheshire, is supplied with 150,000 gallons of water daily, from a well 9 feet in diameter and 120 feet deep, sunk in the new red sandstone.

Trevethin, Waterworks Co., Pontypool, furnish a supply of 150,000 gallons of water daily, from springs flowing from the limestone rock.

Uxbridge, Middlesex, is supplied from two wells, each being capable of yielding 100,000 gallons per day.

Wolverhampton, Staffordshire, is occasionally supplied with water from three wells sunk in the new red sandstone formation, which yield 500,000 gallons of water per day.

Designs of Wells.

In considering the mode of making a well, many important matters have to be thought of, and some unforeseen circumstances may often cause the original plan to be set aside. Under this head it is proposed to give a brief outline of the construction of a few wells.

Birkenhead.—It has been already mentioned that Birkenhead is supplied with water from two wells; for all practical purposes a description of the first well sunk will suffice. This well is entirely executed in red sandstone rock, and without steining. The total depth is 395 feet; the first 95 feet is 9 feet diameter, then follows a bore of 26 inches diameter and 44 feet deep; this is succeeded by a bore 18 inches diameter and 16 feet deep, which is diminished to a bore of 12 inches diameter for an additional depth of 130 feet, and finally this is succeeded by a bore 7 inches diameter and 110 feet deep. The water rises after the cessation of pumping to within 93 feet of the top of the well; and when reduced to a level of 134 feet from the surface, the well yields 2,000,000 gallons of water every twenty-four hours.

Guy's Hospital.—The well is sunk through the London clay into the chalk, and the following is a description of the strata pierced:—8 feet superficial earth, 2 feet yellow clay, 1 foot black loam, 3 feet peat, 19 feet gravel, 63 feet blue clay, 22 feet mottled clay, 4 feet dark blue clay, 5 feet shells and sand, 10 feet mottled clay, 4 feet sand and pebbles, 4 feet mottled clay, green coloured sand and pebbles, 4 feet green coloured sand and pebbles, 3 feet green coloured sand, 44 feet grey sand, succeeded by a layer of flints, and then the chalk. The total depth of the well is 298 ft. 6 in. For 9 feet in depth it is 8 feet diameter, and steined with 9 inch brickwork; which is succeeded by five cast-iron cylinders, 4 ft. 6 in. diameter, each cylinder being 5 feet deep. Below these cylinders, and for a further distance of 96 feet, the well is 4 ft. 6 in. diameter, and steined with 4½-inch brickwork, then follows 2 feet of 9 inch steining, the whole resting on the bottom of the well, which is executed in 18 inch brickwork. In the centre of the well a bore-hole is made, which is lined with a 12-inch iron pipe, the pipe being continued 72 ft. 6 in. above the bottom of the well, and within 60 feet of the surface.

Kensington-gardens.—This is a well that was sunk for supplying the Serpentine. It is 321 feet in depth, and the water rises within 105 feet of the surface. The following is a description of the strata pierced in making this well:—2 feet of surface earth, 170 feet blue clay, 2 feet petrified wood, 7 feet dark coloured sand, 43 ft. 6 in. coloured clays, 1 ft. 6 in. sand, 4 feet pebbles, 30 feet sand, 3 ft. 3 in. flints, 54 ft. 5 in. chalk, 3 ft. 3 in. flints. The well is 6 feet diameter for 203 feet deep, and steined with brickwork as follows:—For the first 25 ft. with 9 in., 67 ft. 6 in. with 4½ in., 5 ft. with 9 in., 10 ft. with 14 in., 5 ft. with 9 in., 91 ft. with 4½ in. The remaining portion of the wall is lined with 4 ft. 6 in. iron cylinders; there are twenty-three of these cylinders in use in the well, and they are continued up the well within the brick steining, a distance of 60 feet. The bottom of the well is filled up with concrete, through which a boring is made and lined with a 12 in. pipe, 18 ft. in length; the top of the pipe is about 5 ft. above the bottom of the well; the remaining portion of the boring is lined with an 8in. pipe.

Cheshunt Well, New River Company.—This well yields 702,000 gallons of water per day, and in its execution the following strata were pierced:—1 ft. 6 in. superficial earth, 8 feet gravel, 45 feet blue clay, 2 feet yellow clay, 12 feet white sand, 39 feet dark coloured sand, then follows the chalk. The well is 171 feet deep, and is steined partly with brickwork and partly with iron cylinders. For 12 feet in depth the well is 11 ft. 6 in. diameter, and steined with 14 inch brickwork; for a further depth of 44 feet it is 9 feet diameter and steined with 9 inch brickwork; of the 44 feet, 41 feet is lined with cast-iron cylinders, 8 feet diameter, which are also carried to a depth of 105 feet from the surface. There are fifteen cylinders of this size in use, and they are succeeded by others 6 ft. 10 in. diameter, of which there are six in use; these are again succeeded by two cylinders, 6 feet diameter. The whole of the cylinders are 6 feet in depth. The bottom of the last cylinder is 118 feet from the surface, at which point they rest upon a foundation of 9 in. brick steining, 7 ft. in depth. At the bottom of the 6 feet cylinders the well widens out in the form of a cone 12 ft. 6 in. diameter at the floor, which is 26 feet below the bottom of the 6 feet cylinders. In the centre of the well a bore hole 3 inch diameter and 27 feet deep was made, and the well is provided on the floor level with headings 7 feet high and 4 ft. 6 in. high.

Amwell Hill Well, New River Water.—This well furnishes a supply of water equal to 2,460,000 gallons of water per day, it is entirely sunk in the chalk; for 84 feet from the surface it is steined with 9 inch brickwork, then follows a sinking 10 feet diameter without steining, but furnished with headings 6 feet high and 4 ft. 6 in. wide. In the centre of this shaft a 2 feet bore is made, which is succeeded by one 9 inches diameter. The entire depth of the well is 161 feet.

Wormley, Herts.—This well is 135 ft. 6 in. deep, and is sunk in the chalk. The water rises to within 61 ft. 8 in. of the surface. For 38 feet the well is 4 feet diameter, at which point it commences to widen, until at 50 feet it is 6 feet diameter, at which size it is continued until 70 feet is reached; the whole of the work is steined with 4½ inch brickwork; for 15 feet deeper the well is 3 ft. 9 in. diameter, the upper portion of which is steined with wooden curbs, the well terminates in a bore 6 inches diameter, and 50 ft. 6 in. deep. In executing this well the following strata were pierced:—1 foot surface earth, 9 feet loam, 10 feet yellow clay, 12 feet blue clay, 6 feet brown sand, 14 feet white sand with pebbles, 20 feet brown sand with water, which was succeeded by the chalk.

Cheshunt—Well of Sir Henry Meux.—This well is 202 ft. 6 in. deep, and derives its supply of water from the chalk. It is an ordinary well, steined with brickwork. The surface water is prevented from entering the well by making the well concentric at the top, the space between outer and inner wells being afterwards filled in with puddle. The well itself is 71 feet deep, steined with 4½ inch brickwork. It is executed for the remainder of the depth by boreholes, varying in diameter from 7 inches to 4 inches. In executing it the following strata were pierced:—5 feet gravel, 59 feet blue clay, 12 feet coloured clay, 1 foot dark coloured sand, 5 ft. 6 in. sand and pebbles, 3 feet bright sand, 35 feet dark sand, 1 foot flints, 2 feet chalk flints, 1 foot flints, the remaining distance of 78 feet being entirely chalk.

Southampton.—The well sunk on Southampton Common, with the intention of supplying water to the town, turned out to be a failure as regards procuring a supply of water, although it is a fine example of the art and skill of the well-sinker. The well is sunk to the depth of 563 feet, and bored a further distance of 754 feet, making a total depth of 1317 feet. The upper portion of this well was executed in brickwork. At 10 feet from the surface iron cylinders, 13 feet diameter, were introduced, which were continued to the depth of 62 feet from the surface, when the contractor failed in his work, which at this depth was 2 feet out of the perpendicular. The work was now undertaken by Mr. Thomas Docwra, a gentleman who has had great experience in well-sinking; but, before the fresh work could be proceeded with, it was necessary to secure and strengthen the upper cylinders, which, owing to the violent measures used to drive them, were cracked and broken in all directions. This strengthening was accomplished by the introduction of cast-iron curbs, suspended from the flanges of the cylinders; and when the work had been in this manner thoroughly secured, the new work was proceeded with: three built-up cylinders, 8 ft. 6 in. diameter, were produced within the 13 feet cylinders, and extending about 3 feet below them; then steining with brickwork was commenced, which gradually widened out until at the depth of 72 feet it was 14 feet diameter; steining was continued to the depth of 164 feet, and was lined within with iron cylinders, backed with concrete; at this depth (164 feet) a set-off was made and the well was continued in 14 inch brick steining, having a diameter of 11 ft. 6 in., until the well had reached the depth of 214 feet, when another set-off was made and the well was continued in 14 inch brickwork, 10 feet diameter, to the depth of 267 feet from the surface; at this depth another set-off was made, and the well was continued in 9 inch brickwork, 8 ft. 6 in. diameter, until the well had reached the depth of 302 feet; when at about this depth it was ascertained that the work would have to be continued through a bed of running sand, and special means were adopted to secure the work above. These means consisted of the introduction of an iron curb, and the work was suspended by iron rods to another curb at the set-off, 267 feet from the surface: this latter curb, in its turn, was suspended by means of strong chains to the bottom of the cast-iron cylinders at 163 feet from the surface. When the work had been thus secured, a single cylinder of cast-iron 8 feet diameter, extending 2 feet within the 9 inch brick steining, was introduced, and below this 4½ inch brick steining, lined with cast-iron cylinders 7 feet diameter, was executed, the space between the brickwork and the cylinders being filled with puddle. A sluice was made in one of the cylinders, which could be opened to admit water at pleasure; at 322 feet from the surface, the use of iron cylinders was discontinued, and the work was carried forward in 9 inch steining, the well being 6 ft. 9 in. diameter, to the depth of 467 feet, at which point the steining was terminated upon 18 inch footings of brickwork bedded in the chalk. The remaining portion of sinking was executed in the chalk, without the use of steining, until at the depth of 563 feet, a trial bore 7 inches diameter was made to an additional depth of 754 feet, when, owing to the great expenses incurred, and the probability that if water were to be reached at all it would be salt and unfit for the purposes required, this enterprise was abandoned.

Wells and borings have been occasionally made for absorbing waste water, which is conveyed into the absorbent strata, and which, being disseminated over a large district, finally makes its escape at the points of natural overflow of the strata. It has been observed that, in making use of wells for this work, any ordinary well will absorb a quantity of water equal to its yield, provided that the water is free from matter likely to choke the pores of the absorbent strata. Thus it has been proved that if the natural water level in a well is 20 feet from the surface, and by reducing the water level to 30 feet from the surface the well will yield 100 gallons per minute, by raising the water level 10 feet from the original level, or within 10 feet of the surface of the ground, the well will absorb water at the rate of 100 gallons per minute. Wells of this description have been executed in many places purposely to get rid of surplus water; thus an extensive plain near Marseilles, which was originally a morass, has been effectually drained in this way. In this country it has often been found that, to carry out agricultural drainage, water may sometimes be got rid of by simply boring through the upper crust of clay or other impervious strata into the porous strata below. Absorbing wells should not, under any circumstances, be used except to take away pure water; as the effect of discharging impure water into these wells would be to contaminate the wells of the neighbourhood used for procuring supplies of water. The practice of making cesspools absorbing wells is a most pernicious one, and cannot be too strongly condemned, as not only may it spoil the water of any wells in the immediate neighbourhood, but when the strata is very porous it may pollute wells and springs more remote.

Necessity of Drainage.

Whenever an artificial supply of water is conveyed into a town which previously has been supplied from wells, it may be found that, without a proper system of drainage or sewage to convey away the surplus water, the healthiness of the place, instead of being improved by an abundant supply of pure water, may be injured, as the constant pumping from the wells of a district tend very naturally to promote the dryness and healthiness of the soil, and when the pumping is discontinued dampness with all its evils are brought into play, which are augmented by the additional supply of water.

ON THE BEST MODE OF APPLYING POWER TO PROPEL TRAINS ON RAILWAY LINES HAVING FREQUENT STATIONS, AND IN TERMINAL STATIONS.*

By Peter W. Barlow, F.R.S.

My attention was first especially directed to the subject of the motive power on railways in the year 1844, when I was instructed by the directors of the South Eastern Railway to report on the applicability of the atmospheric system to the Tunbridge Wells branch of the South Eastern Railway, and my investigation containing some experiments on the Tyler-hill incline of the Whitstable Railway, was laid before the Institution of Civil Engineers in 1845.

In the year 1848, on the opening of the North Kent Railway, the locomotive superintendent reported to me that a much greater consumption of coke occurred than with similar trains on the main line, which was supposed to arise from the smaller radii of the curves and steeper gradients.

The stations being more frequent on this line, it was necessary, in order to understand the cause of this loss, to distinguish what portion of the total power was required to put the trains in motion, as distinguished from that employed in traction, and I calculated the acceleration of trains with varying tractive power, which was compared with the observed acceleration of locomotive trains on the South Eastern and Great Western Railways, and with the experiments made by Mr. Stephenson on the Atmospheric Railway at Dalkey.

It is sufficient for the present purpose to say that, with due allowance for the loss of tractive force with increase of velocity, the experiments fully confirmed the theoretical calculations, and left no doubt of the practical accuracy of the formula. (See Appendix.)

In the progress of these experiments on locomotives, I remarked the serious loss of time which arose in getting the train into speed; and it will be seen by referring to the tables that on the South Eastern Railway, at that time, one and a half to two miles was generally required to get the train into full speed, and, on the Great Western, between three and four miles; and it became apparent, by testing the rate of acceleration due to the tractive power of the North Kent engines, that it was impossible to make the journey (stopping at every station) in the time required, even if the trains had no friction or incline to contend with.

The only remedy was engines of greater tractive power and weight, and these have been adopted to such an extent, to meet all cases, that under favourable circumstances a momentum and velocity is given to the train in 150 yards that would be sufficient to take it half a mile on the level if the engine was detached; and having recently observed this fact, it occured to me that in working metropolitan lines, with frequent stations, sufficient power might be given at the station, by stationary power, to propel the train, without the aid of a locomotive, to the next station; and having, upon careful consideration, arrived at an opinion that such a mode of working will give a greater average velocity, and be apparently superior in other respects to the use of locomotives in such cases, I have been desirous to lay my investigation of the subject before this Society, as a matter deserving of discussion, from its important effect on the capability of metropolitan railways to relieve street traffic.

In the ordinary duty of locomotives, as employed upon the great systems of railways, the distance between the stations or points of stoppage is such, that the great and important duty of the engine is to maintain the requisite speed after that speed has been acquired; and one of the first facts which an inquiry into the subject cannot fail to establish is, that the locomotive engine is admirably adapted for this purpose; and, as regards the fuel expended for a given amount of work, it is one of the most economical forms of engine in use.

The result will appear, whether we take the work performed by an express engine in a fast train, or a heavy goods engine drawing a slow train; and in either case it results that, provided the distance between the stations is large, so that the engine can work for a considerable time, exercising its power at a fair working speed, the economical working of locomotive engines, comparing the work done with the fuel consumed, becomes manifest.

When, however, the duty to be performed is that of working a line in which the stations are very close together, and the stoppages frequent, it then results that all, or nearly all, the work of the engine is expended in acquiring the travelling speed, and that, in fact, it has not ceased to accelerate its travelling speed when it becomes necessary to shut off the steam and apply the brakes, so as to stop at the next station. In fact, the same engine which in long stages would make an average speed of 35 or 40 miles per hour, is incapable, with frequent stations, of making an average speed of 13 or 14 miles, even with a greatly reduced load.

In this condition of things, which is in fact the condition of metropolitan railways, a new set of circumstances has to be met; and the question arises whether, where these circumstances exist, stationary power, when applied in a manner strictly adapted to the case, is not more economical—capable of greater speed—and in all respects more suitable to the convenience and exigencies of the traffic, than locomotive power?

In terminal stations the use of stationary power will add much to the simplicity of working. At present, as the locomotive arrives in front of the train, it is made prisoner until the train is removed. It has then to go to another part of the station to be turned on to take in coke and water, and then comes back again to the train it has to take out. These frequent operations not only wear out the road and points and crossings very rapidly, but cause constant stoppages to trains arriving to enter the station. To avoid a portion of this difficulty, the locomotives are sometimes run tender first, a mode of working which amounts to an admission of imperfection, and appears to foreshadow a change in the present system, particularly as the more the traffic increases the more these imperfections will be felt. When the stations are near together the time required to acquire the speed is so important an element, that greater tractive power is requisite to enable a reasonable average speed to be maintained; and the power of the engine is governed by the power requisite to put the train into motion. Thus the actual power exerted to propel trains of forty tons every five minutes each way on a railway similar to the Metropolitan, of three and a half miles in length, at the velocity now adopted, would not, allowing one-third 214 horses, lost power, and 15 lb. per ton traction, exceed that to obtain which at least ten locomotives, capable of exerting in the aggregate a power of 2200 horses, are required, in consequence of the combined losses from the extra weight to be conveyed, the power to overcome the inertia, and, thirdly, from the engine being restricted from making a fair working speed, these losses being in addition to that of the engine itself from friction, &c.

Seeing that it is necessary to use such powerful engines to passenger trains where the stoppages are frequent, it follows that the weight of the engine becomes large in proportion to the weight of the train, and therefore, if that weight can be dispensed with, much less power will suffice to give the same amount of speed, or, with the same amount of power applied, a much greater speed will be obtained. In like manner, if the weight of the engine is dispensed with, the train can be brought to rest in less time by means of the brake; and coupling this with the increased rapidity with which the speed at starting can be acquired, it follows that, dispensing with the weight of the engine would be of very great advantage in the case of stopping trains. In order to show the disadvantages under which locomotives act when stations are frequent, a comparison is here made of the speed which will be obtained by a locomotive weighing 40 tons having an effective tractive power of 4000 lb., with a stationary engine of the same power, and one of 8000 lb. tractive power, the stations being assumed to be 1000 yards apart, and the railway in the first place level, the second on a gradient of 1 in 200, and the third on a gradient of 1 in 100.

The rate of acceleration is correctly represented by an incline obtained by dividing the total weight conveyed by the effective power, and will be understood by the diagrams on the next page, in which the line-----represents the incline due to the locomotive; the.........line that due to the stationary power with 4000 lb. tractive force; and the line—-—-—-that due to 8000 lb. tractive force. The tables appended show the relative inclines and velocities.

It will be seen, by reference to the table, that in the case No. 1—viz., level, the velocity has been increased from 17½ to 27 miles per hour, and the time saved 41 seconds. In No. 2 gradient, 1 in 200, the velocity has been increased from 15½ to 26 miles per hour, and the time saved 54 seconds; and in No. 3 gradient, 1 in 100, the velocity has been increased from 13 to 25½ miles per hour, and time saved 1 minute 17 seconds.

* Paper read before the Society of Arts.

No. 1.—*Railway Level.*

Power employed.	Incline representing rate of acceleration.	Distance the power acts.	Time of passing 1000 yards		Average velocity per hour
		Yards.	Min.	Sec.	Miles.
Locomotive train tractive power 4000 lb.	1 in 56	794	1	57	17½
Stationary engine tractive power 4000 lb.	1 in 25	455	1	28	23
Stationary engine tractive power 8000 lb.	1 in 12	216	1	16	27

No. 2.—*Gradient* 1 *in* 200.

Power employed.	Incline representing rate of acceleration.	Distance the power acts.	Min.	Sec.	Miles.
Locomotive train tractive power, 4000 lb.	1 in 78	853	2	12	15½
Stationary engine tractive power, 4000 lb.	1 in 28½	523	1	31	22½
Stationary engine tractive power, 8000 lb.	1 in 13	228	1	18	26

No. 3.—*Gradient* 1 *in* 100.

Power employed.	Incline representing rate of acceleration.	Distance the power acts.	Min.	Sec.	Miles.
Locomotive train tractive power, 4000 lb.	1 in 125	905	2	37	13
Stationary engine tractive power, 4000 lb.	1 in 33	405	1	34	21¾
Stationary engine tractive power, 8000 lb.	1 in 13·4	242	1	20	25½

Fig. 4 is given to represent the relative velocities of the locomotive and stationary engines.

It will also be observed that the tractive force of the stationary engine, when double that of the locomotive, has been employed less than one-third of the distance, and therefore greater velocity has been obtained with less expenditure of power; and hence arises an important feature in favour of stationary power, as proposed to be applied, as not only less actual power is required, but a short length only of propelling power being necessary, the loss of power and liability to derangement hitherto experienced in stationary power will, in a great degree, be avoided. The obtaining increased velocity with less power is apparently an anomaly, but its correctness may readily be seen, and will be illustrated by the experiment of applying a tractive power by means of a weight sufficient to propel a carriage with a small acceleration. By applying four times that weight for a quarter the distance the acceleration is very rapid, and the average velocity will be increased with the same expenditure of power, and in degree depending on the ratio of the accelerating power to the load in the two cases. I am, therefore, able to claim for stationary power, when stations are frequent, the advantage of superior speed, an advantage which has been found to be of importance to the success of railways generally, and their influence in the districts through which they pass, and one which there is no reason to doubt will equally influence the development of the traffic of metropolitan railways, if not to a greater degree, because the saving of time is at present less decidedly in favour of railways.

If stations were a little more frequent than they are, a good cab would still remain the quickest mode of travelling; and it is so now, unless the railway runs direct to the point to which a passenger is destined. Speed is also important, from enabling more frequent trains, and therefore a larger amount of traffic, to be carried on one line of railway.

The economy arising from stationary power is not here advanced as of the usual importance in railways, perfection of

Fig. 1.—Railway Level.

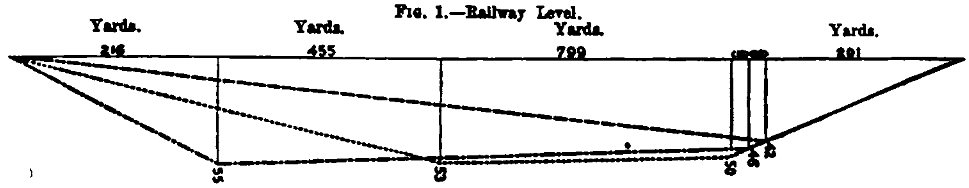


Fig. 2.—Gradient 1 in 200.

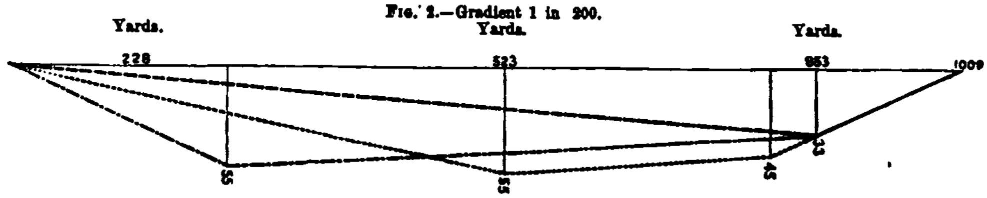


Fig. 3.—Gradient 1 in 100.

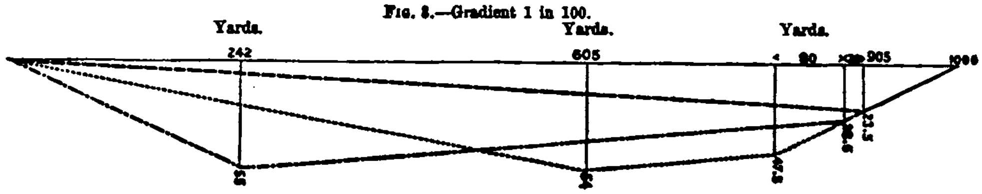
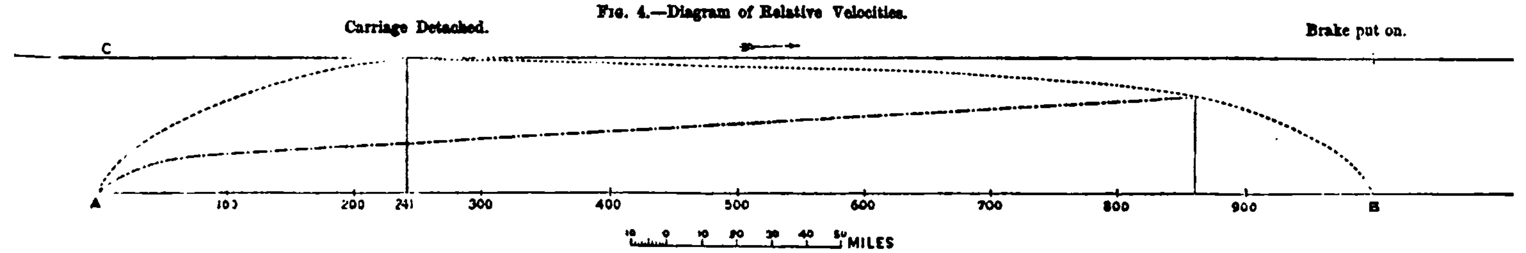


		Fig. 1. Miles per hour.	Fig. 2. Miles per hour.	Fig. 3. Miles per hour.
Locomotive power ------	Average velocity	17½	15½	13
Stationary equal power	,,	23	22½	21¾
Stationary double power —·—·—	,,	27	26	25½

Fig. 4.—Diagram of Relative Velocities.



Scale of Velocities.

Velocity of Locomotive from A to B is represented by dotted line, thus : —·—·—·—·—·—
Velocity by Stationary Power from A to B is represented by dotted line, thus : - - - - - - - - - - - -
Velocity of an Ordinary Train—by a line thus ————————
From E to B represents velocity of a carriage detached at E from the ordinary train.

working being rather the point to be aimed at, as it would pay itself from the development of traffic in a metropolitan railway, even at greater outlay and cost, but as the economy claimed is so great as nine-tenths, with equal velocities, it is necessary to explain how this extraordinary difference arises. That the loss from the use of locomotives on metropolitan lines is fully nine-tenths of the power employed is pretty evident, because the total duty performed in propelling trains of 40 tons every five minutes, equal to 40 tons 84 miles per hour, or 200 tons 16½ miles per hour, is not greater than one of the locomotives employed (which are in fact equal in tractive power to goods engines) would perform on a main line as a fair day's work, and the cause of this loss it is not difficult to comprehend. As before stated, it arises from three causes:—1. The increased weight of the train from the addition of the weight of the engine. 2. The loss in overcoming the inertia of the train, and consequent application of the brake; and 3. The large proportion of the time the locomotive is under steam, as compared with that on which it is employed advantageously in traction. The degree of economy from the weight of the locomotive being saved, of course depends on the relation of its weight to that of the train. On railways worked by stationary engines, the weight and friction of the rope, from its great length, generally exceeds the loss from the locomotives; but in metropolitan railways the locomotives are required to be of such weight as nearly to equal that of the train, and therefore, half is directly lost from this cause.

The loss from overcoming the inertia of the train will be arrived at by comparing the power employed in each case. If the double power represented by the line - - - on the diagram is continued for 100 yards, the velocity on the level will be 27 miles per hour; and if the train is allowed to run by its own momentum it will be 18½ miles at the point where the brake is applied, producing an average of 20 miles, a velocity considerably exceeding the locomotive. The power exerted will be as 200 to 799, or 1 to 4 nearly. This explains a loss of ¾ths of the locomotive power, the remainder, making it $\frac{9}{10}$ths, being due to the locomotive not being an accumulating power; or in other words, the power exerted in the two cases is as 1 to 4, while the engine power necessarily employed is 1 to 10, from the engine being restrained from making a fair working speed.

The case here assumed for illustration is that of the railway being level. On gradients exceeding 1 in 200 it will be necessary to have a greater velocity than is now made by locomotives to give sufficient momentum, and thus a direct comparison cannot be made; in fact, the advantage claimed for stationary power is the means of giving increased speed combined with great economy, rather than that of excessive economy with the same speed. There is no doubt, however, that a saving could be made of two-thirds of the present cost, still giving a large improvement in speed.

Frequent trains are, in the opinion of experienced persons, both in this country and in America, necessary to develope the omnibus traffic; and there is no reason why, with stationary power, from the improved velocity, they could not be made to run every three or four minutes, allowing sufficient time for one train to leave its station before the following train was allowed to start. This could not be done without locomotives treble in number to the stationary engines, even if there were required to be one stationary engine at every station. Another source of economy will arise by stationary power, from less destruction of the permanent way, and in underground railways from a less dimension of tunnel being required when a single line is used.

The two important points of comparision—viz., speed and economy, are here shown to be in favour of stationary engines, and as the avoidance of the locomotive would be a benefit to the travelling public, particularly in tunnels, and equally so to the residents on the line, by reducing the noise and vibration, and is also decidedly conducive to safety, stationary engines would appear to be the superior mode of working railways with frequent stations, unless there arise practical objections to balance these advantages. Two objections have been suggested—one, that the rate of acceleration will be so rapid as to be unpleasant to passengers; and the second, that in the event of a train from any cause being stopped between stations, it would be left in a helpless condition for want of locomotive power.

With reference to the first objection, it is only necessary to observe that the rate of getting into motion will not produce a greater velocity than 11½ miles per hour at the end of 50 feet, which is not so great a rate of acceleration as arises in a carriage propelled by horses; in fact, if the rate of acceleration which now arises with locomotives in descending gradients were given to trains on the level and in ascending, a very important saving of time would be made, and no objection could arise on this point. With reference to a train being stopped between stations, it must be assumed that the momentum given to the train would be such that considerable brake power would be always required to stop it at the next station. The distance the train is to be propelled by momentum is much less than is done every day by detached carriages on the principal lines of railway; in fact, every locomotive train is propelled the latter part of its journey by momentum; and in the case of express trains more than a mile is required to stop, with the assistance of brakes. The Greenwich and Blackwall railways were worked into London by momentum nearly as far as is here proposed, and were never known to fail as long as the engine power acted properly. The cause of interruption to the traffic by an accident to the locomotive itself will be avoided, and that which now occasionally arises from the repair and renewal of the permanent way will be much reduced. On a metropolitan line devoted exclusively to passenger traffic, there are no level crossings, and the public are entirely excluded, so that the stoppage of the train, except from accidents, will be very rare, and no train would leave one station until the line was signalled clear to the next. A pilot locomotive, in case of accidents, would be used as at present, as the mode of applying the stationary power will not prevent the occasional use of locomotives.

On the mode of applying the stationary power.—The mode of applying stationary power here suggested differs from that hitherto employed, inasmuch as it is not connected from station to station, or connected through several stations, like the Blackwall system, but each has a propelling power independent of the other, although the power may be derived at several stations from one engine. It also differs in that the power is used accumulatively, and thus a smaller power of engine is required.

I will now observe that the result of the experiments on the Whitstable railway, previously referred to, and the examination generally of the subject of motive power, led me to recommend the directors of the South Eastern railway to substitute locomotives, and abandon the stationary engines on that line; and the alteration was attended with satisfactory results, not because there was any serious difficulty in the rope system, except its great weight and length, but because one locomotive was made to do the work of all the stationary engines, and a greater average speed was obtained. One of these ropes was 1 mile 70 chains in length; and on the Blackwall railway the rope was above 3 miles in length to carry passenger traffic. Great mechanical skill and good workmanship is indicated by the fact that such a piece of machinery could be kept in order for any length of time, because the actual weight put in motion and inertia to be overcome, in addition to the train, was much greater than that of a locomotive, besides the friction of five hundred sheaves. These cases, however, prove that no practical difficulty or liability to derangement is likely to arise in the use of a rope for 150 or 200 yards only, as is now proposed; and it may be here remarked, that although ropes have been superseded by locomotives in many cases, yet that still a large amount of traffic is carried on by ropes; and in one important instance, viz., Glasgow, the locomotives have been again abandoned for the rope, on an incline of 1 in 43, for 1 mile 14 chains used for passenger traffic.

The mode which first occurred to me of applying the stationary power for the present purpose, was by Sir W. Armstrong's hydraulic principle to give motion to a rope, which system has the advantage that one engine can be made to do the work of several stations by a water-main laid along the line. Another form of propeller, very simple in its action, but requiring an engine at each station, is the descent of a weight raised by a small engine constantly at work.

The power expressed by a weight of 40 tons raised 30 feet every two minutes and a half would propel a train of 40 tons more than 1¼ mile on the level before it came to rest; and a stationary engine of forty-eight-horse actual power, allowing one-third loss, would be sufficient to run 40-ton trains every five minutes each way, allowing for the loss from friction and the power required to bring the weight to a state of rest, which latter loss would amount to 10 per cent. of the power. The cost of working such an engine, including repairs, would not amount to £2 10*s.* per day, so that the cost per train per mile would be under 2*d.* The trains may also be propelled on the atmospheric principle, either by the old plan of a pipe, or Mr. Rammell's plan of a small tunnel; and as the power is required only for a short distance, there will not arise the difficulty from friction and leakage which has hitherto been experienced in these modes of traction.

In another form of propeller suggested, which is specially adapted to frequent trains, the accumulation of power is made in the boiler. Driving-wheels and cylinders, similar to a locomotive, are used to propel a rope for the required distance. The total weight of moving machinery will not in this case, including the rope, exceed 4 tons. A duplicate of every part, including the boilers, would be provided, and as there is an interval of eight hours' rest in each day, sufficient to replace any part which might be out of order, I submit that such a piece of machinery may be considered nearly safe from derangement. A propeller of either kind, it is suggested, could be used advantageously on railways worked by locomotives, for the purpose of starting trains from stations situated at the foot of inclines, where now locomotives, although generally master of their work, frequently fail in surmounting the incline, thus leading to loss of time and danger.

In conclusion, I will observe that it is difficult for the author to describe a new suggestion without a bias in its favour, but I have endeavoured to lay the comparative merits of stationary and locomotive power fairly before the meeting. The subject is so important in its influence on the value and extension of metropolitan railways, that I offer it for discussion without venturing to give a decided opinion of my own, until I hear the views of those eminent engineers who have devoted their attention to the subject of motive power, and which views, I hope, will be expressed on this occasion.

APPENDIX.—The formula used in calculating the acceleration is:—

$$v = 2\sqrt{\frac{P \pm \frac{T}{I} - \frac{T}{2240f}\,S.\,16\tfrac{1}{3}}{T}}$$

I being the inclination of the railway; P the tractive power; T weight of train in lb.; S length of the plane; f friction of the train per ton.

The velocity given to a train of 40 tons by 4000 lb. falling 600 feet, or 8000 lb. falling 300 feet, the friction being 1t· lb. will be:—

$$2\sqrt{\frac{(8000-600)\quad 300 \times 16\tfrac{1}{3}}{89,600}}$$

$$2\sqrt{\frac{(8000-600)\quad 300 \times 16\tfrac{1}{3}}{89,600}} = 27 \text{ miles per hour.}$$

The power exerted will be for five-minute trains.

8000 lb. falling 300 feet in two minutes and a half,

$$\text{or } \frac{8000 \times 300}{2\tfrac{1}{2}} = 940,000 \text{ lb. in one minute.}$$

$$\frac{940,000}{33,000} = 28\tfrac{1}{2} \text{ loco. power} \times 5 = 142{\cdot}5$$

add one-half 71·25

213·75

In the discussion which followed—

Mr. BARLOW said, before he described the experiments he had to bring before the meeting, he wished to add a few remarks to what he had written. In suggesting a substitute for the locomotive, he had no intention to undervalue the qualities of that engine; on the contrary, he regarded it as the masterpiece of mechanical engineering, and the results it produced were perfectly astonishing, as also was the amount of duty it was capable of performing; he entertained the highest respect for those men whose talent and thorough knowledge of the subject had brought that machine to its present state of perfection. He appeared before them, therefore, not as an opponent of the locomotive, but rather as a great admirer of it; and he merely suggested that this noble machine, when employed as the motive power on a railway of short length and frequent stations, was not able to exercise more than about one-tenth of its power. What he (Mr. Barlow) submitted was, that under certain circumstances stationary power might be employed with advantage; and because it had failed under other circumstances there was no proof that it would not succeed under those which had now arisen. The alteration he suggested in the application of stationary power consisted in this—that instead of applying that power between station and station, he applied it for such a distance that the momentum, or *vis viva* of the train, was brought into play, and this was as much a force as the force of steam, and could be depended upon as well as any other force. He proposed to apply the power of the rope for such a portion of the distance, that the momentum of the train would carry it with perfect certainty to the next station. The advantage of applying it for a portion of the distance, and allowing it to act in that way, arose from a particular law of accelerating forces, from which it resulted that a greater tractive force applied for a portion of the distance would accumulate a momentum that would give greater speed than a smaller tractive force applied for the whole distance, the actual power being the same in each case, because the greater force acts for a proportionately less distance. (Mr. Barlow then proceeded to illustrate this principle by a model of a carriage propelled by means of a weight suspended.) By applying four times the tractive force for a quarter of the distance only, he obtained greater velocity over the whole distance than by applying the tractive force for the whole distance. The difficulty with regard to stationary power hitherto had been the great length and weight of the ropes; but with short ropes, he submitted, they could manage the machinery perfectly well. Another experiment was shown, to prove that by reducing the weight of the carriage by about one quarter, double the velocity was obtained with the same amount of motive power. This was brought forward to show that where the duty of the locomotive engine was an accelerating and not a tractive power, by relieving the train of the weight of the engine, they did more than save the mere weight of the engine, and therefore produced a greater economy on lines where there were frequent stations than on lines where the duty of the engine was entirely of a tractive character. The principle of accelerating force was further illustrated by the motion of a ball rolled down first a gentle incline, and then down a steep incline, and so carried by its momentum up a gradient to the same level as before, but with a greater velocity. This explained why a greater velocity was obtained when the same power was employed over a shorter distance.

Mr. IMRAY said that as, in the course of several conversations with Mr. Barlow, that gentleman had asked him to look into his calculations, he would now venture to state his opinion as to their accuracy, and to explain as briefly as possible the view he took of the principle on which Mr. Barlow had based them. It might at first sight be difficult to understand how, by a temporary impulse given to a train, instead of a continuous traction being applied to it, there could be an economy of power for a given speed, or an increase of speed for a given power. The illustration which Mr. Barlow had given of a ball rolling down one incline and thereby acquiring momentum sufficient to carry it up another incline, appeared to him to embody the whole principle under discussion, and he would endeavour to apply, as clearly and as briefly as he could, the same principle to the case of a railway train running on a level. From the experiments made by Pambour, it appeared that the resistance to the motion of a train amounted on the average to 10 lb. per ton, or $\frac{1}{224}$th of the weight in motion. The experiments conducted by the British Association seemed to show that this resistance amounted to about 8 lb. per ton, or about $\frac{1}{280}$th of the weight. Since those experiments were made, great improvements had been effected, both in the carriages and in the permanent way; but without laying any stress on that circumstance, he would merely take the mean of the above figures, and state the resistance as about 9 lb. per ton, or about $\frac{1}{250}$th. It might, in fact, be taken that a train in motion was subject to a constant retarding force equivalent to that which it would, without friction, encounter in running up an incline of 1 in 250. If then a train were started with the velocity which it would acquire in descending such an incline, it would, leaving friction out of account, ascend that incline before its velocity entirely vanished. Assuming that the stations were 1 mile apart, and that it would be desirable for the train to retain a certain amount of speed, say 7 or 8 miles per hour, to be overcome by the brakes on reaching the farther station, the length of the incline might be taken at 6000 feet. The gradient being 1 in 250, the total height of the incline measured from base to summit would thus be 24 feet. In other words, a train descending through 24 feet of vertical height would attain sufficient velocity to carry it 1 mile on the level, retaining at the end of the mile a velocity to be arrested by the application of the brakes. The power necessary to effect this upon a train weighing 40 tons, or 89,600 lb., would be $89,600 \times 24 = 2,150,400$ foot-lb., or equivalent to the work of a 65-horse engine during one minute. As to the mode of giving this velocity, he would not trouble the meeting with any remarks, for that was rather a question of practical engineering than one of figures, to which he now wished to confine himself. Let it, however, be assumed, for illustration, that the velocity was given to the train by causing it to descend an incline of 300 feet in length. The total descent being 24 feet vertical, this would give an incline of 1 in 12½, or a tractive force of 721 lb. for a 40-ton train; and whether the velocity were given by the descent of such an incline, by the application of rope traction, or by any other means, the power expended and the result produced would be precisely the same. As the objection which would, no doubt, be raised to Mr. Barlow's system, because the velocity would be too rapid, or rather too suddenly imparted, he was of opinion that it was quite groundless. The rate at which a passenger was put in motion in a cab or omnibus considerably exceeded that contemplated in the case in question. Any one that had taken a trip on the "Montagne Russe," where the descent was something like 1 in 4, must have experienced a start something like three times as sudden as it would be in the case under consideration, and he (Mr. Imray) would observe, for his own part, that the sensation on the "Montagne Russe" at starting was rather pleasant than otherwise. To quote another instance, that of the Cycloidal Railway, where the passenger was inverted in his progress towards the terminus, the descent at starting was something like 1 in 2, and certainly no unpleasant shock was occasioned at the start in this apparently perilous journey. He regretted having occupied the meeting with dry figures, but he trusted that he had succeeded in confirming the truth of Mr. Barlow's calculations, and he had only to thank his hearers for the patient attention with which they had listened to his observations.

Mr. Zerah Colburn remarked that he had no doubt the system now brought forward possessed advantages in respect of the working of underground railways, especially in avoiding the nuisance arising from the vapours of combustion from the locomotive engine, and it would save much of the great wear and tear of the permanent way caused by the locomotive itself; but, it seemed to him, when they had got so far all the advantages of the proposed system were at an end. He did not know whether Mr. Barlow had proposed to adapt the railway to the system, or the system to existing railways. If it was proposed to adapt this system to the Metropolitan Railway, he would apply it to the case of the King's-cross and Gower-street section on that line. The distance between those two stations was 50 chains, or five-eighths of a mile, with a gradient of 1 in 100, or a total rise of 33 feet. A train to arrive at Gower-street from King's-cross must, upon the proposed system, start with a velocity at least equal to that which a body would acquire in falling from a height of 33 feet. This would be expended in overcoming gravity only, but they had also to overcome the friction and the resistance of the atmosphere. Instead of the sum of these resistances being only 15 lb. to the ton, he believed the experiments made on the Metropolitan Railway showed that the resistance at the moderate speed employed on that line was something like 25 lb. per ton. He would take $22\frac{4}{10}$ lb. per ton as a convenient figure. Thus, in order to get over the gravity and other resistances over that distance, the train must start at a velocity equal to that of a body falling from twice 33 feet, or 66 feet. But it would not do to run into Gower-street station by the simple exhaustion of the momentum of the train. It should have a terminal velocity of at least 15 miles an hour to be extinguished by the brakes. In order to do that, the falling body assumed would have to fall from an additional height of 7½ feet; therefore the train must be started with a velocity equal to that of a body falling 73½ feet in order to arrive at the intended point on that gradient. The velocity required would be something like 70 feet per second, 66 feet per second being equal to 45 miles an hour, and that would hardly be a proper rate at which to start in order to get over the short distance between those two stations. The question was whether it would be safe or prudent to start at that speed. Would the carriages bear the great strain necessary to produce it? Would they keep the rails? Then, again, the whole of the power applied to the train was to be expended within a distance of 300 feet. A train of 40 tons weight was assumed, but this he believed was but about half the maximum weight of the trains on the Metropolitan Railway, irrespective of the engine. To give a train of even 40 tons a velocity of 66 feet per second, starting up this incline, would require the exertion of about 6,300,000 foot-lb. of mechanical power, which had to be put into the train in a distance of only 300 feet, so that the constant force must be equal to 21,000 lb., or nearly three times the maximum power of the engines now employed on the Metropolitan Railway.

Mr. Barlow said the speaker was arguing upon entirely wrong premises.

Mr. Colburn inquired within what distance the power was to be applied?—Mr. Barlow replied 242 yards.

Mr. Colburn added, that brought the rate down in the proportion of 726 to 300; but his argument was merely to illustrate the case of 300 feet, which had been mentioned. It would be a most rapid acceleration of speed, even if the distance were twice and a half what he had supposed to be intended. The power was applied very suddenly, and the starting must be at a rate of 45 miles an hour to do the distance between the two stations, and he did not think either the carriages or the line could stand that, even if it were not productive of great inconvenience to the passengers themselves. Besides, he had heard no mode suggested by which that velocity could be obtained within so short a distance, nor did he yet see how the power was to be connected with the train without causing violent shocks. On these points he should be happy to hear Mr. Barlow's explanation.

Mr. Seymour Teulon would feel obliged if Mr. Barlow would explain the manner in which he proposed to connect the rope with the train for so short a distance, and also how he proposed to disconnect it.

Mr. Barlow replied that the length of the rope depended upon the gradient to be worked. If the gradient were 1 in 100 it would require a greater length of rope, and the steeper the gradient the more advantageous was this system. The mode of detachment from the rope was precisely that adopted on railways at the present time—viz., by means of a pin.

Mr. T. Marr Johnson thought Mr. Barlow had lost sight of the extreme inconvenience of fixed plant. It was the great difficulty which attached to the atmospheric and pneumatic systems. Let them imagine the inconvenience of a break-down of the engine. Mr. Barlow said there were eight hours of the twenty-four left for repairs; but on the Metropolitan Railway there were only four hours. In case of a break-down, Mr. Barlow had said there would be a pilot engine to get over the temporary difficulty, but this could not work the traffic. If there occurred a break-down of the engine or rope, the chances were it would take a week to repair; and even with plant in duplicate it might take a day. If the traffic of the Metropolitan line were stopped for a day, 30,000 people would be prevented from travelling over it, which would ultimately have considerable effect upon the dividends of the shareholders. It was absolutely necessary, not only that the trains should be run with great frequency, but that they should also run with the greatest certainty, or travellers would be deterred from using the line. Another consideration with respect to the adoption of this system to the Metropolitan line was the fact that that line was worked in connection with the Great Western and Great Northern railways. The trains of those lines could not possibly be worked partly by locomotive and partly by rope traction. Locomotives must work the long traffic, and might therefore as well bring the train on to Farringdon-street. The truth was, moreover, that in order to get over the difficulty of a break-down of the machinery, it would be necessary to keep eight or ten locomotives in stock.

Mr. Burnett said that the tractive force required to propel the trains on the Metropolitan Railway up the incline of 1 in 100 between King's-cross and Gower-street was 6900 lb. for a train of 70 tons. Deducting the weight of the locomotive, which might be assumed as one-third of the whole train, the force required would then be two-thirds of the 6900 lb.

Mr. Thos. Webster, F.R.S., said the subject before them was one of much interest, and they must all feel indebted to Mr. Barlow for having brought forward a proposal having for its object to obviate what was, no doubt, a great difficulty in the working of a railway like the Metropolitan. All engineers, he believed, had come to the opinion that it was desirable, if possible, that some other system of working these lines should be adopted. The locomotive engine was no doubt one of the most perfect machines ever invented, and the amount of work it was capable of doing was astonishing; but when they considered it was adapted, in the first instance, to the working of long lines, carrying enormous weights, with few stoppages as compared with the metropolitan system, which involved a great number of stoppages, the time he thought had arrived when they should endeavour to provide some other means of propulsion on the metropolitan system, which was being so rapidly extended, particularly as in long tunnels the foul air from the locomotive was a serious nuisance. At the same time it could not be denied that, as was stated by Mr. Johnson, the difficulties in introducing either the rope, the atmospheric, or the pneumatic system on such a line as the Metropolitan were very great; but he thought it was no answer to the proposition before them, to say there were difficulties in the way of its adoption. They must look at the whole question, because he thought there was a strong feeling on the part of the public, and of many engineers, that the whole system of working these metropolitan lines must be reconsidered. If there were so, although they must admire the great skill with which the Metropolitan Railway was worked, he thought a proposition coming from a man of Mr. Barlow's practical experience ought to be received with the greatest consideration. The atmospheric principle, judging from former experiences of it, he apprehended was quite out of the question, and the pneumatic system was as yet almost untried. The question was a most important one, and Mr. Barlow having brought it before them—not as an amateur—not as a mere adventurer, but as one who had had a vast amount of experience in the working of railways, he hoped it would receive, as it deserved to do, most careful attention.

Mr. Chas. Vignoles, F.R.S., believed that theoretically and mathematically Mr. Barlow's calculations were accurate. He would say, with regard to what had fallen from Mr. Johnson, that the difficulties attending the break-down of the stationary machinery were not much to be apprehended. Both the atmospheric and rope systems had worked for many years without any failures from the breaking down of the engine. He thought, as far as the ordinary practical working of a line was concerned, the stability of fixed engines as they were now made might be entirely depended upon, particularly if duplicates were supplied where necessary; but with these admissions he was not prepared to say that the system of working metropolitan lines by stationary rather than by locomotive power had arrived at that degree of ripeness that they could adopt it. The atmospheric system was worked for many years, with some failures, but the truth was it did not pay, from a variety of causes. He was not aware of the precise reason why the rope on the Blackwall line was abandoned; but he could quite understand that on a line perfectly open a comparison between the locomotive system and stationary engines would be very much in favour of the former. But, now they had railways under ground, there were a variety of circumstances, chemical, sanitary, and otherwise, which altered the nature of the case very materially. He quite agreed with Mr. Webster that the time had come when they should seriously discuss the desirability of working these metropolitan lines by other means than the locomotive now in use. He was not prepared to say Mr. Barlow's system was the best. He thought that gentleman had underrated the power of resistance, though perhaps Mr. Colburn had overrated it, and therefore he thought the motive power calculated on by Mr. Barlow was too low; but in his opinion sufficient had been said to show that the stationary system was worthy of trial. He apprehended it would be difficult to get that trial, owing to the great expense it would involve, and he did not think an experiment on a small scale would be successful. With all Mr. Barlow's mathematical talent, he thought the system was hardly ripe enough to be brought into practical operation, though he felt indebted to him for having brought the subject forward.

Dr. Bachhoffner remarked that the sanitary question, in connection with underground railways, owing to the nuisance in tunnels arising from the vapours of combustion from the locomotive, was a very important one. He expressed his surprise that during the discussion no allusion had been made to the description of locomotive, which he understood had been modified by Mr. Fowler to such an extent, that it gave out no vapour whatever during the passage through a tunnel. In fact, it was a gigantic tea-urn, with a heater inside of sufficient capacity to keep up the steam, while passing through a tunnel, without any products of combustion escaping from the furnace. He was not aware whether that kind of engine was generally employed on the Metropolitan Railway. As far as he gathered of the mode of attachment of the train, it appeared to him that both in the attachment to, and attachment from the rope, a very sudden jerk to the passengers must be occasioned.

Mr. S. Teulon said, when he asked the question as to the mode of attaching the carriages to the rope, he did so as one materially affecting every system of rope traction where the rope was not continued from one terminus of the line to another. He believed the rope on the Blackwall line was abandoned in consequence of its connection with other lines, worked by the locomotive, rendering that system inconvenient. He fully agreed with the opinions expressed by Mr. Webster and other speakers that, where a railway consisted mainly of tunnels some other mode of traction than the locomotive should, if possible, be adopted; but he doubted whether in practice it would be desirable to have a series of either weights or stationary engines, because there would be a difficulty of detachment as the carriages arrived at each station. It was stated in the paper that with frequent stations on a metropolitan line, worked by locomotives, a journey could be accomplished quicker in a cab with a good horse than by the railway, and he should be glad to hear whether, under the present system proposed, the journey by railway would be expedited. He apprehended that unless the train was started at a greater speed by this system than by the locomotive they would be in the same position in that respect as they were now. With regard to the jerk at starting, they all knew that if the driver turned on the steam too quickly at first, an effect not pleasant to the passengers was produced. Although a system of rope traction might be a very good one where the stations were close together, and where all the carriages were attached to the same power, so that they could not have one carriage overtaking another, they must remember that on all the metropolitan lines they had to provide for the arrival of locomotives from long distances on other lines; because he did not understand that the rope system was proposed to be adopted throughout the country. He had much desired to call the attention of Mr. Barlow to difficulties which at present he had not shown how he could overcome.

Mr. R. K. Bowley begged to remind the meeting that Rammell's Pneumatic Tube had been at work regularly for a long time at the Crystal Palace without interruption or accident. He would not give any opinion on its merits, but would merely state this fact for the information of the meeting.

Mr. Chubb, having been connected with the management of a metropolitan line for the last ten years, would say, it struck him that the suggestions of Mr. Barlow amounted to a return to a system which he regarded as altogether exploded. The rope traction on the Blackwall Railway was an utter failure. Mr. Robert Stephenson stuck to his child till he could endure the creature no longer. It was not only ruinous to the traffic, but the cost to work that traffic with anything like regularity was enormous. It was not abandoned, however, on account of the difficulty of junction with other lines, for it was quite practicable to effect this by covering over the rope at the points of junction. The rope, however, was perpetually breaking, and horses had to be kept ready to bring it home after the difficulty of catching the broken ends had been accomplished. The introduction of the rope system on that line had caused an addition to the capital of the company of not less than £100,000; and, after every possible material for the rope had been tried, all of which failed, it was happily abandoned for the system of locomotive traction. He considered the motive power ought to accompany the train, and he believed the right thing to do was to deal with the locomotive itself, and endeavour to modify its construction so as to meet the requirements of the new system of railways that had been commenced, but he earnestly begged them not to return to the rope system.

Mr. Burnett thought the alleged deterioration of the atmosphere in the tunnels of the Metropolitan Railway had been much exaggerated. He referred to the fact of the enormous traffic which was daily carried on that line, as a proof that it was not viewed with disfavour by the public, and remarked that, if the engines which were run from the lines in connection with the Metropolitan were as free from the vapours of combustion as were those employed by the company, there would be no cause of complaint on that account. With reference to the alleged vitiated atmosphere in the tunnel stations, he would state that fans were introduced, to bring down the good air from above, and drive off the bad air from below; but after they had been a little time in operation the officials begged they might be removed, as it was questioned whether the air brought down was not worse than that which existed in the tunnel.

Mr. Joseph Smith remarked that the fact was lost sight of, that the journey from Bishop's-road to Farringdon-street was accomplished in eighteen minutes, which was a very short time to pass in even a confined atmosphere. He should be sorry to be left in one of the tunnels of the Metropolitan line, as he had often been on the Blackwall line through the failure of the rope system.

The Chairman said it now became his duty to ask the meeting to accede to a vote of thanks to Mr. Barlow for the interesting paper with which he had favoured them on a subject which was exceedingly important, not only to engineers, but to all who travelled by railways, especially on the metropolitan lines. It appeared that Mr. Barlow had brought before them a system, novel in many respects, though not essentially so. Mr. Barlow had told them that on a line where the stations were very frequent, they might with advantage employ a means of propulsion that was not available where the stations were more distant apart, and where the length of rope required would be exceedingly great, and had maintained that, by employing fixed engines and using rope for short distances, there would be a great saving of engine power, and reduced expenditure in the general working of the line. He had also shown that, by taking advantage of accumulated momentum, an economy of power and an increase of speed could be obtained, but he had omitted to notice the important consideration of securing a much purer atmosphere within the tunnel. They must recollect that, in the construction of lines for which the sanction of Parliament had already been obtained, tunnels of greater length than anything they had on the Metropolitan would occur. This would be so on the line from Victoria-street, under the Thames embankment, to Blackfriars, and also on the proposed East London line, of which the Thames tunnel was to form a portion, and these being at much greater depth from the surface rendered the question of purity of atmosphere a still more important one. It was one of these engineering problems which should meet with full and careful consideration. It was satisfactory to find the calculations of Mr. Barlow supported by two able mathematicians, Mr. Imray and Mr. Vignoles. They were told that a great objection to fixed as compared with locomotive plant was the liability of derangement in the machinery; but this fear was originally expressed with regard to steamers, and yet those who had taken long sea voyages must have been struck with the undisturbed regularity with which the engines of steam vessels were worked, almost without cessation, for weeks together, which was sufficient, he thought, to dissipate all fears in connection with derangement of machinery. With regard to casualties, it should not be forgotten that it was proposed to have duplicate engines, and therefore the chances of a serious breakdown in working this system were very trifling. He apprehended the purpose of this discussion was to ascertain the real merits of this system, for it must be remembered that we had to deal with what might be termed an entirely new class of railways, and therefore some improvement in the present mode of working seemed to be required. He confessed he hoped this was only one of many discussions which they would have in this room, by which they might find a better mode of travelling underground than any hitherto adopted. Mr. Johnson argued from the large number of persons who travelled on the Metropolitan Railway, that the system was as good as it could be; but if a better system were introduced, he (the chairman) contended, more people might be induced to use the line. He concluded by moving a vote of thanks to Mr. Barlow for his paper, which was carried unanimously.

Mr. Barlow, in acknowledging the compliment, said he would endeavour to answer the objections that had been brought against this system of propulsion. With reference to the Metropolitan Railway, he had said very little about that line in particular, but he had said he thought locomotives were very cruelly treated on lines with frequent stations, and on the Metropolitan line cruelty was carried to the greatest extent, inasmuch as the locomotive was prevented from breathing whilst going through a tunnel, in order that the passengers themselves might be able to breathe. With regard to the figures given by Mr. Colburn about traction, he thought that gentleman must have mixed up those figures with something in which he had been engaged on the other side of the Atlantic, as they had nothing in this country in the way of traction that agreed with his statements. With respect to what had fallen from Mr. Chubb relative to the system of rope traction formerly employed on the Blackwall line, it was no argument that because a thing had failed under certain conditions, it should not succeed under entirely different conditions. He (Mr. Barlow) had had very great experience in rope traction, and he was acquainted with all the difficulties connected with it. He was aware of the loss of mechanical power which was occasioned by the rope; but in the case of the Blackwall Railway the great wonder was that it ever worked at all. It was a rope more than 3 miles long; and the difficulty of working a rope increased by more than the square of the length; so that it was no argument to say that because a rope of 3 miles failed, therefore a rope of 300 yards could not succeed. With regard to the starting of the train, it had been objected that under the rope system there would be an unpleasant jerk, but this was not so much the case as under the present system, for with locomotives the couplings of the trains were frequently slackened when it was standing at a station, and the result was, when they put on the steam each carriage received a jerk at starting. He had been assured by Sir William Armstrong, and other eminent practical men whom he had consulted on this subject, that under this system a train could be started more gently than by a locomotive. The rate of speed at which it was proposed that the train should be started was not necessarily higher than under the present system with a locomotive on a descending gradient. Moreover, if by the rope system they could make the uphill start and travelling as good as the downhill at present, they would effect a material improvement. Besides, when it was considered that under this plan of propulsion trains could be run every three minutes, they would not have such heavy trains to deal with as at present. On the subject of rope traction he would say, further, he believed he was the first to abandon it, on the Whitstable branch, and the example was followed on several other lines, including the Glasgow; but, in the latter instance, they were obliged to come back to the rope again; and for a distance of nearly a mile and a quarter a large passenger traffic was carried on by rope traction at the present time, and hence it could not be contended that any practical difficulty would arise with a rope of 300 yards. Objection had been made to the rope system, on the ground that it interfered with junctions; but the proposed mode of applying the rope traction for short distances entirely obviated the difficulty.

THE COMPULSORY SALE OF LAND REQUIRED FOR PUBLIC UNDERTAKINGS IN ENGLAND.

(Continued from page 26.)

Settlement by Jury.—In cases to be settled by verdict of a jury, the promoters must give to the owner ten days' notice in writing of their intention to cause a jury to be summoned, and in this notice also make an offer of the amount which they are willing to pay for the lands required, and as compensation for the damage done by reason of the execution of their works. At the expiration of ten days, unless the owner in the meantime require the question to be settled by arbitration, the promoters issue a warrant addressed to the sheriff, requiring him to summon twenty-four persons qualified to act as common jurymen in the superior courts, to meet at any convenient time and place, to be mentioned in the summons, the time being not less than fourteen or more than twenty-one days after receipt of the warrant, and the place not more than 8 miles from the lands in question, unless by consent of the parties. The sheriff gives notice to the promoters of the time and place, and the promoters are to give not less than ten days' notice of the same to the owner. If the sheriff is interested in the matter, there are provisions for the warrant to be executed by the coroners, or the ex-sheriffs, should the parties so desire.

Out of the jurors summoned, twelve are drawn by the sheriff, as in the superior courts. If a sufficient number of jurymen do not attend, and both parties do not consent to proceed with the number in attendance, the sheriff may return other duly qualified persons of the bystanders or others, to make up the proper number. All parties have their lawful challenges against any of the jurymen. A special jury may be summoned at the instance of either party; if the owner so desire, he must give notice to the promoters before they issue their warrant. No juryman can be required to attend any of these proceedings more than once a year.

The sheriff by himself, or, as is usual, by the under-sheriff as deputy, presides at the inquiry; the claimant is considered the plaintiff, oaths are administered to the jury and witnesses, and the inquiry is conducted by counsel, much in the same way as an action at law in the superior courts. A view of the premises by the jury may be ordered, on the application of either party. The sheriff is subject to a penalty of fifty pounds if he make default; and the jurymen to the same regulations and penalties as if they had been summoned in any of the superior courts, in addition to a penalty not exceeding ten pounds, to be applied towards the cost of the inquiry. Witnesses failing to appear, or refusing to be examined, are liable to a penalty not exceeding ten pounds, payable to the party aggrieved. If the claimant does not appear, the inquiry does not proceed; but the compensation to be paid is ascertained by a surveyor appointed by two justices, as hereafter mentioned.

The verdict is to be given separately, when such a case arises, for the money to be paid for the interest of the claimant in the lands, and for the compensation to be paid for severance or injuriously affecting other lands belonging to him. It is common, however, for the parties to consent to the jury giving a verdict for the whole in a lump sum; when this is done, it is usual to take the substantial verdict as the finding of the jury on one issue, while a nominal amount is put on the other, so as technically to comply with the requisition of the act. The judgment and verdict are to be recorded in the office of the clerk of the peace, who is to give certified copies to all parties applying for the same. The record is evidence in the superior courts, and so soon as it is completed, an action for debt can be maintained by the claimant against the promoters. If the verdict be given for a greater sum than that which has been offered by the promoters, they are to bear all the costs of the inquiry; but if the verdict be for the same or a less sum, or if the owner have failed to appear after proper notice, then each party bears his own costs, and half the costs of summoning and empanelling the jury and taking the inquiry. The costs in case of difference are to be settled, on application of either party, by one of the masters of the Court of Queen's Bench. If the costs be not paid within seven days after demand made by the party entitled, they may be recovered from the promoters by distress, or may be deducted from the compensation to be paid to the owner, as the case may be.

On an inquiry before a jury, the title of the claimant to the land in question must be taken for granted, and the only point to be left to the jury is the value of the land and the compensation for damage. One of the leading cases on this point is that of Chabot *v.* Lord Morpeth. The claimant was owner of land required by Her Majesty's Commissioners of Woods, &c. for the formation of Battersea-park. The most valuable portion of the land was frontage to the river Thames, and outside the river wall. It was elicited on the inquiry that the tide occasionally flowed up to the river wall and over the land in question. The counsel for the commissioners, Sir John Jervis, the then attorney-general, started the proposition, that as the tide flowed over it, the land must belong either to the Crown or the City (who were then disputing as to the right of foreshore), and not to the claimant; the jury so found, and awarded a sum for the land inside the wall only. After various proceedings in the superior courts the verdict was quashed, on the ground that the jury had nothing to do with the title. The case was afterward referred to arbitration, and a sum awarded for the river frontage, to which it seemed the claimant was really entitled. It therefore appears that in the case of a wrongful claimant the promoters must proceed with the inquiry as to the compensation, but on their refusing to pay over the amount determined the claimant would have to bring his action, and must then show his title.

Proceedings in the case of Absentees and others.—The compensation for lands to be taken from any party who by absence from the kingdom is prevented from treating, or who, after diligent inquiry, cannot be found, or who shall not appear at the time appointed for the inquiry, after due notice thereof, is to be determined by the valuation of a surveyor appointed by two justices on application of the promoters. Before entering on his duties, such surveyor is to make a declaration, in form prescribed, that he will faithfully and honestly execute the duty imposed upon him. The nomination by the justices, and the declaration, are to be annexed to the valuation when made, and are to be preserved by the promoters, who must at all times produce the same to the owner and all other parties interested, when so requested. The expenses of, and incident to, such valuation are to be borne by the promoters. The amount of compensation so ascertained is paid into the Bank of England, to the account of the accountant-general of the Court of Chancery; and the claimant, when he appears, applies to the court for payment of the same. If, however, the claimant is dissatisfied with the amount so deposited, he may, before application to the court, by notice in writing to the promoters, require the question to be submitted to arbitration; this arbitration is conducted in the manner before described, and the question to be submitted to the arbitrators is, whether the sum deposited is sufficient, or whether any and what further sum ought to be paid or deposited. If the arbitrators award a further sum, this is to be paid or deposited, as the case may require, within fourteen days after the award is made. If the arbitrators determine that the sum deposited was sufficient, the costs are to be in the discretion of the arbitrators, but if a further sum is to be paid, all the costs are to be paid by the promoters.

As to Lands already taken.—It will be seen that the proceedings hitherto described relate only to cases in which lands are *proposed to be* acquired by the promoters, who are to take the initiative in proceedings for obtaining possession. It happens occasionally, however, that by some means possession is really obtained without complying with these preliminaries, or a case for compensation arises during or after the actual execution of the works.

Under these circumstances the claimant has to take the first step, and by section 68 of the Lands Clauses Act it is provided that, if any party be entitled to compensation for any lands that *shall have been taken* for or injuriously affected by the execution of the works, and for which the promoters have not made satisfaction, if the claim exceed the sum of fifty pounds, he may have the same settled by arbitration or jury as he thinks fit. The claimant must give notice in writing of his desire to the promoters, and state in such notice the nature of his interest in the lands, and the amount of compensation claimed. If within twenty-one days after receipt of the notice the promoters do not enter into an agreement to pay the amount, the same is to be submitted to arbitration, if the claimant has so desired. If the claimant prefers a jury, the promoters must issue their warrant to the sheriff within twenty-one days after receipt of the notice, or they will be liable to pay the full amount of claim which can be recovered from them by action.

Obtaining Possession.—The promoters cannot, except by consent of the owners and occupiers, enter on any lands required to be purchased until they have paid to every party having any interest in such lands the compensation agreed or awarded to be paid to them respectively. In the case of absentees and others, as before mentioned, or parties under disability, or where the owner refuses to accept the compensation agreed or awarded, or if he refuses or neglects to convey the property to the promoters, or fails to make out his title to the same, the promoters may deposit the amount in the bank in the name of the accountant-general, and may execute a deed poll, containing a description of the lands, and reciting the purchase or taking thereof, and of the default having been made; and thereupon the interest in respect of which the deposit has been made vests absolutely in the promoters, and they are entitled to immediate possession.

Often, however, owing to the various delays which take place in the negotiation or settlement of the compensation, the promoters are desirous of taking possession before an agreement has been come to or an award made or verdict given, and they then take advantage of the powers given to them under the well-known 85th section of the Act, which enables them to deposit in the bank either the amount claimed or such a sum as shall be determined to be the value of the lands or of the claimant's interest therein, by a surveyor to be appointed by two justices, as provided in the case of absentees above mentioned. The promoters must also give to the parties interested a bond in a penal sum, equal to the sum deposited, with two sufficient sureties, to be approved by two justices if the parties differ, and conditioned for the payment of all such compensation as may be determined to be payable to the parties interested, or for deposit of the same in the bank as the case may require. On the deposit being made and the bond delivered or tendered to the non-consenting party, the promoters may enter into possession. The money so deposited remains at the bank by way of security to the parties interested, and on the conditions of the bond being fully performed is repaid to the promoters on their application.

The surveyor appointed by the justices has no power to examine witnesses or call for documents, and he may not be able to get at the real facts of the case, and the amount of compensation is eventually determined in the ordinary way, without reference to the sum which has been deposited under the provisions of this last-mentioned section.

Whenever possession is taken by the promoters without consent of the owner, interest at the rate of five per cent. per annum from the day of entry is payable by the promoters on the sum eventually determined to be due.

If the promoters or their contractors wilfully enter and take possession without consent, or without paying or depositing the compensation in manner provided, they are liable to forfeit to the party in possession the sum of ten pounds over and above the amount of damage done by such entry, the penalty and damage to be recovered before two justices, and if after conviction they continue in unlawful possession they are liable to forfeit twenty-five pounds for every day they so remain in possession, recoverable by action in any of the superior courts. The promoters are not liable, however, to these penalties if they have bonâ fide paid the compensation to or made a deposit in respect of any person whom they may have reasonably believed to be entitled thereto, although it should turn out that such person has really no legal interest in the matter. Any person having an interest who has not been dealt with as provided by the Act in his case, may obtain an injunction from the Court of Chancery to restrain the promoters from entering or proceeding with their works on his land until they have placed themselves in a position lawfully to do so. This latter is the remedy more frequently resorted to by owners, as the promoters are with reason much more frightened at the probable expenses of a chancery suit than they are at the penalty for their wrongdoing which is to be inflicted by the justices.

All moneys directed to be paid into the bank to the account of the Court of Chancery remain to the benefit of the parties entitled, and are paid to them or reinvested for the like trusts or uses as the lands in respect of which the money was deposited, or as the court may direct on application of the parties. All costs of paying in and payment out of court, of reinvestment, and all reasonable charges incident thereto, are to be borne by the promoters.

Intersected Lands.—If any lands not in a town or built upon are intersected by the works, so as to leave on one or both sides a quantity less than half an acre, the owner may require the promoters to purchase the same with the land to be taken, unless he has other land adjoining into which it can be thrown so as to be conveniently occupied, and if so, the promoters at the request of the owner must at their own expense remove the fences, level the sites, and soil the same in a sufficient and workmanlike manner. In the like case, on the other hand, if the owner require the promoters to give him a bridge or other communication to the small piece so cut off, and the expense of making such a communication as he would be entitled to be greater than the value of the land cut off, the promoters may require the owner to sell the same to them; and any dispute as to the value of the land or the expense of making the communication is to be settled as provided for in cases of disputed compensation.

Copyholds.—With regard to the purchase of copyhold lands, the promoters must first get the conveyance to them entered on the rolls of the manor of which they are holden. This the steward is to do on payment of his proper fees. Within three months after this enrolment, or within one month after the promoters have entered on the last of any parcels which they require holden under one manor, whichever shall first happen, they must apply to the lord of the manor to enfranchise the whole of the lands taken, and pay to him such compensation as may be agreed or settled, as in cases of disputed compensation. On payment or deposit, as the case may be, of the compensation, the lord is to enfranchise, and in default the promoters may execute a deed poll, with the same rights as in other cases of refusal. The apportionment of customary rents, &c. is to be agreed between the owner of the lands and the lord of the manor on the one part, and the promoters on the other, or in case of dispute to be settled by two justices.

Common Lands.—The compensation to be paid in respect of the ownership of the soil of any land subject to rights of common is settled with and paid to the lord of the manor, or other party entitled, who is to convey the land to the promoters. The compensation to be paid for the common or other rights, and also for the soil, where it belongs to the commoners themselves, is to be settled with a committee of the parties entitled to such rights. The promoters convene a meeting of the commoners, to be held at some convenient place in the neighbourhood of the lands, for the purpose of appointing such committee. The meeting is to be called by advertisement inserted once at least in two consecutive weeks in some newspaper circulating in the county and neighbourhood of the lands, the last of such insertions being not more than fourteen or less than seven days prior to such meeting. Notice of the meeting must also be affixed to the door of the parish church where such meeting is held, not less than seven days previous to the holding, and if the lands are parcel or holden of a manor, the like notice must be given to the lord of the manor.

The meeting appoint a committee not exceeding five of the commoners. The decision of the majority of the meeting binds the minority and all absent parties. The promoters settle, as in other cases, the amount of compensation for the extinction of all commonable or other rights, and all matters relating thereto, with this committee, whose receipt, or that of any three of them, for the compensation is an effectual discharge for the same.

If, after being duly convened, no meeting takes place, or if a committee is not appointed, the compensation is to be determined by a surveyor appointed by the justices, as provided for absentees. Upon payment or tender of the compensation to the committee, or any three of them, or deposit in the bank, the promoters execute a deed poll as before described, and thereupon the lands vest in the promoters, freed and discharged from all the commonable and other rights in respect of which the compensation has been made. P.

(To be continued.)

THE CONSTRUCTION, TRACTION, RETARDATION, SAFETY, AND POLICE OF RAILWAY TRAINS.*

By W. Bridges Adams.

Waggons and carriages are kept short on railways in order that they may roll round curves. Viewing a train of waggons from a bridge, every waggon will be seen to oscillate from side to side on the rails, following the course of curves and irregularities. Every waggon is drawn by a loose coupling-chain, some 18 inches in length, and the oscillation is so violent, that though goods and coals suffer it, and suffer from it, it would be unendurable by passengers, so the carriages of passenger trains are close-coupled together to keep them steady. But in this process the wheels, as constructed, are debarred from following their own courses, and are compelled to slide. The result is a great wear of flanges and axle-brasses, and a large consumption of coke. Were a train of goods waggons as close coupled as the passenger trains it would be simply impossible to move them The first thing an engine-driver does, when about to start a goods train, is to back the whole of the waggons one on to another, and then start them one at a time in succession, by snatch after snatch at each chain, which is therefore required to be of enormous strength, in proportion to the resistance of the vehicle to traction by reason of bad structure.

The necessity for close-coupling the passenger trains arises solely from want of the efficient structure to induce free movement, to make each carriage tractable instead of resisting—docile, and not wilful. The first thing is to attain great length to prevent pitching movement, just as is the case with vessels on water. But with long vehicles, radial movement of the axles must be attained, as described in a former paper. Radial movement may be obtained by radial axle-boxes to the end wheels very effectually with one pair or two pairs of central wheels to serve as fulcra on the rails, or with frames of iron fixed to the axle-boxes and guided by the traction rod and buffer. The traction rod in such cases will serve in the same mode as a carriage-pole on the highway. And swivelling buffer-springs will, by coupling-chains attached to the iron frames, keep the wheels in the right position while backing the train on curves. Or if two pairs of wheels, coupled together at each end of the frame, be arranged with a quadrant or a pivot over one axle and a radial curved bar over the other axle of each pair, they will be self-guided on the rails, and a carriage 30 feet long may thus roll round a curve of 50 feet radius, and the steadier will it run, and the less will be the likelihood of getting off the rails, and moreover the less will be the proportionate dead weight of the vehicle to the available load it carries, if it be rightly constructed.

* Paper read before the Society of Arts.

The Americans and other people use long carriages with swivelling trucks supported on a centre pin, which also have eight wheels, and thus radiate the axles imperfectly, though, if the trucks have not length enough, say 2 feet more than the width of the gauge between each pair of axles, they will not run steady, but will drag their wheels. If the radial system be applied, it would be quite possible to make carriages 40 feet long, with eight wheels, to roll round a curve of 60 to 80 feet radius. A rough model of a vehicle of this description is on the table, and the guiding apparatus of the wheels is not intended for a bogy carrying the load, as in the American carriages, but simply a radial guide, the load of the upper frames being borne by the springs on the axle-boxes, with facility for elastic sliding, or swinging on long vertical shackles.

Some time back a series of medical papers appeared in the 'Lancet,' on the subject of the injury experienced by a certain class of patients from railway travelling. The fact was strongly denied by railway authorities, and by many persons in good health who were not authorities. Not long back a railway engineer who had been very doubtful of the injury, informed the writer that he had changed his opinion, for, being out of health, and desiring to travel backwards and forwards to Brighton, he found he could not do it, on account of the injury caused by the vibration.

It may be remembered that, when the Brighton line was first opened, numbers of City stock-brokers and merchants took houses at Brighton, and yearly tickets to travel up and down daily: in short, to live at Brighton, and transact their business daily in London. The writer has been informed that many ceased the daily practice at the end of the month, and at the end of six months it was found that hardly any could stand it and preserve their health. Now, what is the reason of this? The carriages were as comfortable and easy, and as well ventilated as an ordinary sitting-room, when not in motion, and the only difference therefore could be, that the sitting-room is stationary, and the carriage moves. But what is the kind of movement? There must be something peculiar in it, for physicians to order their nervous patients to travel by road, and not by rail. There are two mechanical differences. The road carriage has wheels proper, with independent movement and elastic wooden spokes, and elastic springs, and the wheels roll over a rough but not constantly hard surface. Riding in an omnibus along Cheapside, the rider finds the stone pavement hard and irregular, and the iron pavement much harder, though regular; and the iron pavement is the most unpleasant of the two. The rail carriage has a kind of iron garden rollers for wheels, and they run on a small but hard iron surface. If the carriage be travelling at a mile an hour, as when starting from a station, the movement is scarcely perceptible, but when at 30 to 40 miles an hour, the vibration becomes unpleasant to most, painful to many. In slow movement, the wheels can adjust themselves to the rails, or roll or slide easily. In rapid movement they have no time to adjust themselves, but slide as well as roll with incessant jerking. On very sharp curves the movement is sometimes all sliding. It is this sliding which constitutes the difference. We may illustrate it as follows. Everybody knows that the sound of a violin is induced by rubbing the horsehair string of a bow over the strings of a violin, both being in tension. But the simple horsehair will not produce the effects. To produce sound, the player applies powdered resin to the horsehair, to induce friction; and it is the leaping of the particles over the strings that induces the vibration resulting in "sweet noise." Sometimes, they who love loud laughter better than sweet noise, will, as a practical joke, apply a tallow candle surreptitiously to the horsehair bow, instead of resin, and then the vibration causing the "sweet noise" is stilled. Now the wheels on a rail are a contact of practically rough surfaces, which vibrate and induce torsion of the axle, and thus vibrate and jump, and the result is, not "sweet noise," but very unpleasant noise and jarring, which, if long enough continued, make a nervous passenger ill, and tend more or less to counteract the peristaltic motion of the intestinal canal. If the rails and tires were rubbed with the tallow candle before alluded to, the vibration would cease, at least till sand enough had accumulated to counteract the effect of the tallow. But the engine-driver would not approve of this plan, as it would lessen the power of haulage. How, then, is this vibration to be lessened? Firstly, by lessening the hardness of the rail, and rendering it elastic. Secondly, by rendering the wheels elastic. Thirdly, by permitting wheels or tires, or both, to revolve independently of each other. Fourthly, by radiating the axles so that neither on curves nor straight lines will the wheel flanges be ground against the rails. Fifthly, by efficiently springing the carriages, using a double series of springs, as well known in private carriages. Sixthly, interposing a non-vibrating material, such as india-rubber, between the carriage body and frame. Seventhly, by so constructing the bodies that passengers may stand or sit at pleasure. The blood cannot circulate freely when in a sitting position. Sedentary employment is a common source of paralysis.

The next question is that of brakes in absorbing momentum by friction. When a large mass of material is put in motion, it requires at first a much greater amount of power to start it into motion than it does to keep up that motion when speed is attained. The power required to get up the speed is called momentum, and if it be required to stop the momentum, it must be absorbed by friction or gravity. If the stopping-places of railways were always on ascents, there would be no need for brakes; gravity would supply the place of friction. And if the starting-places were always on descents, little surplus power would be needed to produce momentum, as gravitation would furnish it. But momentum has to be absorbed under many varying circumstances—sudden obstacles to be averted or stopped short of—stoppage at stations—and the descent of long inclines; also the ascent of long inclines, in case of couplings breaking, or wheels slipping.

In the early times of tramways, the Convoy (*convoi*) or brake carriage was used with the train. In the early times of railways, brakes were applied to first-class carriages, each worked by a guard, because the first-class were the heaviest. But people who paid first-class fares demurred to this, and sliding brakes were adopted, working on the wheels and axles without attachment to the body, and thus jar was lessened, but noise was increased, and so the brakes were transferred to second-class, and then the old convoy—the brake van—was revived, one at the head of the train next the tender, and the other at the tail, and, when the train was heavy, one in the middle. But it was to a very small portion of the total weight of the train that the brake power was applied, and the guards screwed down the blocks tight, and so skidded the wheels and ground places on the tires; and to apply brakes rightly, every wheel in the train should have a brake-block applied lightly to it, from the engine to the last carriage. The engine should have brakes pressing on both rails and wheels, applied by the driver, through the agency of steam friction, by simply turning a steam-cock, the pressure being divided between the rails and wheels in any convenient proportion. Brakes on every vehicle in the train and on all the wheels would reduce the pressure required on each to a minimum. The system of "continuous brakes," as they are called, is applied to as many vehicles as the power used can reach. But the power used is commonly hand-power, and that is limited.

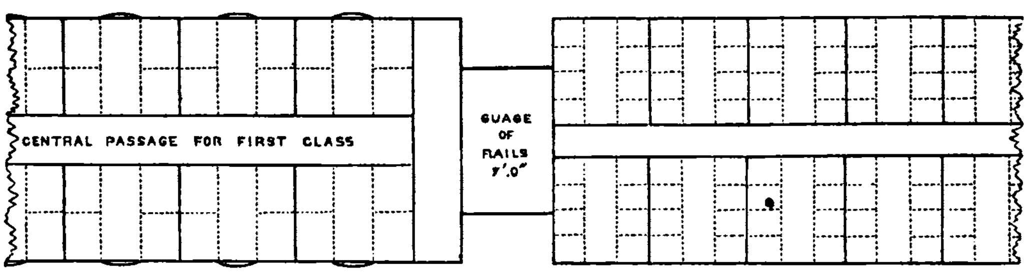
A new mode has lately been adopted on the North London line, of making the momentum destroy itself. On this line of short mileage and many stations, with frequent trains, it would not be possible to work the traffic without the means of rapid stoppage, *i.e.*, the utmost rapidity short of concussion. For this purpose, a chain of sufficient strength to draw the whole train is extended beneath and throughout the train. When this chain is drawn straight, the blocks are all on to every wheel, and when the chain sinks into a succession of curves or bights, by a weight beneath each carriage, the brakes are all off. To draw the chain straight, a pair of heavy cast-iron disc wheels, with a barrel or drum on their axle, are then suspended in slings below the last carriage. The guard, by means of a screw, brings these suspended wheels into close contact with the running wheels of the carriage, and the friction causes the disc wheels to revolve by the momentum, and to wind up the continuous chain on the barrel till it is drawn straight, and the brakes are all on, when the disc wheels begin to slip, and the momentum of the train is absorbed by the brakes. In this mode, a train of fifty vehicles may be stopped in as short a space as a single vehicle, the right amount of friction being applied to each. This arrangement, however, requires either that the chain be carried through the whole train, and accurately connected with the proper lengths of chain to each carriage, the whole train being pulled close together; or that the brake-van at one end, and the engine at the other, serve as fixed points to lift the counterbalance weights and draw the chain to a straight line. There is no doubt of this acting well on trains fitted for the purpose, but the writer has not yet seen it applied to mixed and irregularly made up trains.

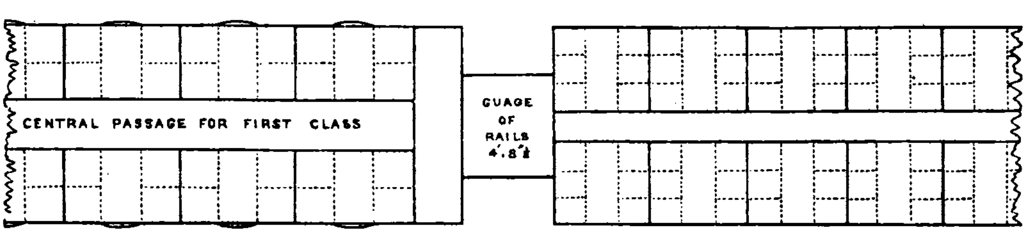
With regard to the application of brake-blocks, there is an advantageous and a disadvantageous method. If applied to the fronts of the wheels, that is, in the direction of the pulling engine, they do not chatter on the wheels, whether fast or loosely applied, but when brought into contact with the backs of the wheels they do chatter, till the pressure becomes very strong, so strong indeed as to skid the wheel. The longer the block, *i.e.*, the longer the surface of tire it embraces, the less is the chatter. But it would be far better to arrange the blocks between adjoining wheels, so as to press both rail and wheels, and in this mode there would be no chatter.

But though the continuous brakes before described act so well on continuous trains of vehicles, the action depends wholly on the continuity of the chain, as well as quick movement to apply them. If the chain separates, the brake action ceases at once, and this on a steep gradient might be disadvantageous. It is therefore desirable to have the brakes self-acting, if possible, without depending on the human hand, and operating on every vehicle independently of the others—operating instantaneously when required. The writer was led to study this question, owing to the necessity of enabling the brakes to follow the wheels of radial carriages on curved courses.

To put this in practice, brake-blocks are suspended from cross-shafts attached to frames resting on the axle-boxes of the wheels. To these blocks long weighted levers are fixed, which cause the blocks to press against the wheels, with either a steel-yard action, or what is called an elbow-joint, four blocks being used, one to each wheel, with two levers or rods to cross-bars. Thus the normal condition of the blocks is, to be pressing on the wheels with a power sufficient for the purpose. The lever ends are attached to the brakes-rod by a chain passing between two pullies on the carriage-frame, and as in the process of traction the rod moves lengthlong in the carriage to either end, the chain lifts the levers vertically, the traction force of each vehicle being sufficient for this purpose, and this process operates on every vehicle so fitted, even though ordinary vehicles be interspersed in the train; and in ascending an incline, if a traction-coupling parts or brakes, these self-acting brakes will instantly press on the wheels before back movement of the wheels can commence; and in going down-hill the brakes will be lifted while the engine is pulling, but will be in action directly the engine is slowed, and they may thus go on pressing and lifting, and so moderating the speed down an incline. It may be objected that the power of the brakes might thus be in excess, and so be a disadvantage, but to equalise this every vehicle is to be provided with a hand-lever, which will enable the driver to put temporarily out of action as many brakes as he may choose, leaving in action the number required for his purpose. The model of the carriage on the table is on a length of rail which may be placed on the level, or at angles of one in 1, in 20, 60, 50, 40, 30, 20, and 10. It will be found that brakes so applied will retain the vehicle on an incline of 1 in 15, and by snatching the brakes rapidly off and on, starting and stopping may be rapidly performed. In practice, the ends of the levers may have sliding balance weights applied, so as to increase or diminish the pressure by the length of the leverage. It must be borne in mind, that the tractive force required to draw the waggon while running must govern the weight required to be lifted at the brake levers, and in cases

BROAD GAUGE.





NARROW GAUGE.

where much weight is needed, the mechanism for lifting must be arranged accordingly. When the whole of the wheels are provided with brake-blocks, a comparatively slight pressure on each tire will suffice. The longer the vehicle, the longer may the brake-lever be, and the more effective will the vehicles be, both for goods and passengers. Coal waggons are made short, for the convenience of getting close to the pit's mouth; but the model on the table, representing a waggon 30 feet in length, will roll round curves of 50 feet radius, and by its great steadiness will carry the coal—a very friable substance—with far less breakage. And a long waggon may be made considerably lighter in proportionate dead weight than two short ones, thus adding to the available load. In these days of competition in coal transit, this is a very important consideration. The self-adjusting brakes described will work equally well, whether the engines be on straight lines or sharp curves, as the levers are arranged to act equally well in either case. And as it is needful occasionally to back the train, for which purpose the brakes must be out of action, this may be accomplished by connecting the traction-rod to the buffer-rods or buffers by spring agency, so that the thrust of the engine may lift the chains and brake-levers in succession, and put the whole out of action, or they may be lifted by hand-levers, as at present practised. This class of brakes is especially adapted to steep gradients. There is nothing new in the principle now proposed. It is the safety principle in the cages of mining-shafts, and on some railways with rope traction.

The last question we have to deal with is what we may call the police of railway trains. This is a question of structure. Trains are subject to catch fire on the roof; passengers may be taken suddenly ill; murders may be taking place, or other violence; but the sound of the train deadens all other sounds, and neither driver nor guard knows of it. And so there is an outcry for communication between passenger and guard, and guard and driver. And there are propositions for galleries outside the carriages, for guards to walk along and catch murderers in the act. It seems to be forgotten that this facility for the guard would also be a facility for the thief or murderer. The practicability of these things is not considered. It is common to talk of the "6-foot" between the two lines of rails as giving ample space for the guard's gymnastics, forgetting that the "6-foot" is reduced to 2 feet by the overhanging carriages, and that two guards on opposite lines would thus come into collision, and, in American phrase, be "rubbed out."

If the guard is to patrol the train, there is but one way of doing it—through the inside—a passage-way through the whole length of the train. Third-class would probably not object to this, as they are disposed to be gregarious, and would not object to a guard or policeman additional; but second-class might object, and first-class assuredly would, on the score that they had paid their money for space and privacy. If it were put to the vote there is little doubt that the vote would be for privacy and a certain amount of risk, rather than gregariousness without risk. It must have been a matter of observation to those witnessing the starting of trains, how first-class passengers walk along till they find an empty compartment, and, failing in this, make for one with the fewest occupants. And second-class will do the same.

Were the lines single there would be no difficulty, as the carriages might be widened at least to the full extent of the tunnels, but with double lines the "6 foot" is the limit, and sometimes the "6 foot" is only 5 feet, and even less. With the 6 feet it would be practicable to have carriages 2 feet wider, provided only that the passengers would consent to have a wire guard to the windows, limiting the protrusion of their hands, like the grating to the windows of a Spanish house. With a carriage 10 feet wide, it would be quite practicable to have a closed passage in the centre, 2 feet wide, and compartments for four persons each, thus getting rid of the objectionable centre seats. The external doors would be retained, and there would be sliding doors inside opening into the central passage, communicating with end platforms. The second-class and third would dispense with the closed passage. Sliding docrs, glazed, would prevent the entrance of wind or rain through the central avenues. In this mode it would not be merely on the guard that the passengers would rely for protection, but also on the facility of intercommunication with each other in case of necessity. But if the brakes were all left to the driver, as they should be, the guard would have ample leisure to attend to the police of his train, instead of having his time taken up with the mechanism. Great Western carriages in the first-class are divided length long by a partition, with the disadvantage that the compartment next the platform on the near side has to serve as an ante-room to the other. If the carriages were 2 feet wider this difficulty might be avoided by a central passage. No doubt this might be all very much simplified by making the whole train a series of open saloons, as in America, but public taste must decide this; and even in America they are now beginning the system of private compartments. With the exception of occasional alterations at platforms, it would be quite a practicable thing to widen the whole of the existing carriage bodies, by dividing them in the centre longitudinally, and inserting the extra width, as ships are occasionally dealt with to lengthen them. And there would be one considerable advantage, that by widening the train the length might be shortened, or a larger number might be carried. It may be objected that a small number—four persons—in one compartment might involve risk in plotted crime; but it would be quite practicable to make one side of the vehicle closed, and the other open compartments.

As a matter of safety in case of collision, the larger carriages are preferable, as they do not mount on each others' backs. As regards the expenditure of momentum by sudden stoppage, which throws passengers violently in each others' faces, the safe remedy would be sitting sideways instead of fore-and-aft; they would be shoulder to shoulder, and in the safest position; but even in this case it is possible that they would prefer the ordinary position with risk, to side-sitting without risk, at least till they had a practical verification by frontal damage to their persons. The subject is so large that the writer has only dealt with it summarily, but a useful purpose will have been answered should the paper have given new materials for thinking.

In conclusion it will be well to help the memory of the reader by a summary of the various propositions contained in the two papers, having reference to the amendment of corresponding defects:—

1. Spring tires, for the purpose of preventing blows and friction, and lessening the chances of the wheels escaping from the rails, a system thoroughly verified in practice, as quadrupling the durability; illustrated by a woodcut. (See *ante* pages 2-8.)

2. Systems of elastic permanent railway, supporting the rails by continuous elastic bearing, preventing disintegration of the rails, as verified in practice; illustrated in timber and metal, by woodcuts.

3. Improved system of fish-joints, duplicating the strength, with elastic fit of ribs and bolts; illustrated by a woodcut.

4. Radial axle-boxes, to enable locomotives of great length to pass round any sharp curve without friction on their flanges—in practice; illustrated by a woodcut.

5. Eight-wheel tank engines, for sharp curves of 99 feet radius, long verified in practice; elevation and plan illustrated by woodcut.

6. Eight-wheel tank engines, for curves of 99 feet radius, all eight wheels drivers, both on straight lines and curves, by means of super-improved friction-wheels, all capable of retardation by steam brakes, making the whole weight of the engine available for traction or retardation; illustrated by woodcut.

7. System of V flanges to spring tires working into V grooves of rails, to obtain increased bite for ascending steep inclines, or when starting with heavy trains; illustrated by a woodcut.

8. System of long waggons and carriages on eight wheels, radial axles, and guided by quadrants, with sliding springs, or long swinging shackles, to roll truly round curves of from 40 to 80 feet radius, and provided with self-acting brakes, to prevent accidents on steep inclines—economically and easily carrying large loads.

9. Mode of constructing passenger carriages to give free internal circulation to guard, engine-driver, and passengers, without interfering with the privacy of first-class passengers; illustrated by woodcut in plan.

These principles and plans are applicable to all gauges, from 7 feet to ‿ ft. 6 in. light lines.

LECTURES ON ARCHITECTURE AT THE ROYAL ACADEMY.

By Sidney Smirke.

On a former occasion, in this place, I dwelt on the paramount importance to an architect of the study of the general composition of his designs; and I expressed the opinion that, however admirably executed the details may be, however gracefully the subordinate and smaller parts of a design may be treated, if the general outlines of the building are unsatisfactory, it will surely fail to please the educated eye. I told you of instances of the impressive effect produced by the flimsiest and rudest constructions—works, perhaps, composed of mere scaffold-poles and tarpaulins, owing to a judicious and artful arrangement of lights and shadows, and to the general proportions of the various masses. We might look around us and not be at a loss to find instances where a superabundance of swaggs and scrolls, and other like objects of minute decoration, display an excessive attention to details, to the total neglect of the far more important consideration of the *general composition of the design*. I will not deny that I am the more disposed to repeat this warning, because the very least observant of us must perceive that this inordinate and too exclusive elaboration of details is one of the vicious tendencies of the present day. We are prone to run into the error of supposing that, be the outlines of our masses ever so tame, ever so deficient in symmetry, we shall yet not fail to secure admiration if the surface of our work be covered with intricate enrichment, so as to captivate the eye with a sumptuous display of elegant friezes and delicate embroidery.

Such were the warnings which I deemed it my duty to address to you on a former occasion; but, in doing so, let me not be so misunderstood as to be supposed to have encouraged carelessness or inattention to those minor objects of ornamental design, which, while we depreciate the habit of attaching too much importance to such superficial details, are, nevertheless, the source of real beauty and pleasure when used with moderation and judgment. It appears to me, indeed, of so great importance that these lesser matters of art should not be disregarded, that I purpose to devote this evening wholly to the consideration of them.

I believe that the best teachers of the sister arts, whether their teachings be written, or conveyed by the still more impressive mode of example, and by their own actual practice,—we shall find, whilst they have of course paid their first and deepest attention to general composition, and to the great elements of beauty of style, yet have never permitted themselves to forego a due attention to the execution of details.

It is always with very great diffidence that I venture to allude to the sister arts, but I feel sure that I am justified in saying that the greatest masters of painting, such as Michelangelo and Correggio, whose genius was especially conspicuous in their grandeur of conception and greatness of manner, never slighted their smallest details, never laid themselves open to the comments of criticism on this score, by showing any want of thought or care in those minor matters, which more slovenly or less competent painters might fancy to be beneath their attention.

Raffaelle, in an especial manner, illustrates this truth. Remarkable as he was for all the loftiest qualities of artistic genius, he never failed to pay delicate attention to his accessories, and to the careful painting of all his details. It was the remark of one of our former presidents, Sir T. Lawrence, when enthusiastically recording his admiration of Sir Joshua Reynolds, that delicacy of finish and careful imitation as much distinguished his works as that noble breadth and largeness of style which placed him at the summit of his art in this country. And again, when adverting to Michelangelo, he said that, "whilst the ceiling of the Sistine Chapel was wonderful for its unequalled breadth and for loftiest conception, and might be regarded as the noblest work ever yet projected, yet even the miniatures of Julio Clovio were not more highly finished than some of the studies of the great masters."

Again, with great deference to my better informed colleagues who cultivate the art of *sculpture*, I would venture to say there also the best sculptors have ever shown a scrupulous regard to the subordinate portions of their work. It has often been deplored by the warmest admirers of that truly great genius, Flaxman, that he should have dimmed the lustre of his works by a too frequent disregard of finish.

If we look back to the brilliant era of ancient sculpture, few things present themselves more calculated to excite our surprise and admiration than the surpassing excellence of their details. The horses in Phideas's friezes are not only wonderful for the spirit and truth of their design, but we shall find on examination that the sculptor has with loving and lavish hand thrown art into the minutest details—the representation of the veins, and the delicate execution of the manes and tails. Although the work was destined to be placed upwards of 60 ft. or 70 ft. from the eye, yet these extraordinary men loved their work too well to admit of their leaving unfinished or unconsidered these small matters, although they must have been well aware that no eye could appreciate them when raised to the position assigned to them in the main work.

I have dwelt long on the evidences of the value attached by the highest authorities to a careful attention to detail in the cognate branches of art; but certainly to no branch of art does the observation apply more forcibly than to that which engages our attention this evening. The works of the architect are usually on a far larger scale, and therefore subordinate parts may not unfrequently derive even undue importance from their size and unavoidable conspicuousness. In our art the high quality of grandeur is more dependent on actual magnitude than is the case in the sister arts. The architect may even be able to win applause by the forcible effect obtained from the mere bulk and extent. Yet still our art has this in common with the sister arts, that whatever praise a building may obtain by reason of its meritorious proportions, or of the grandeur of its general effect, those merits are so greatly increased, and the pleasure derived by the critical eye is so materially, enhanced by the discovery of those smaller beauties of design that are revealed only by a close and critical examination of the subordinate parts, that we can never venture to be indifferent to the value of such details.

Now, it would be easy to show you that such has been the opinion of most men of great artistic genius at all periods. The same niceties that I have been adverting to as forming one of the great charms of Greek sculpture, are equally observable in the *chefs-d'œuvres* of Greek architecture that have survived for our study and instruction. Perhaps it would be difficult to cite a more remarkable instance than the entasis of the shaft of a Greek column. It was found that, owing to some optical illusion, the shaft of a pillar of which the sides are parallel appears to be larger at top than at bottom, and such appears to be the case in the remarkable Egyptian example at Beni Hassan, which has often been referred to as the prototype of the Doric order. To remedy this defect, the Doric architects diminished their shafts upwards of about ⅙th of their bottom diameter. But then, owing to some other optical illusion, it was found that where the sides of the arch were diminished in straight lines from the bottom to the top, those sides appeared to be slightly concave; this gave rise to the adoption of what is called by Vitruvius the entasis, by which expedient this disagreeable *deceptio visus* was at once obviated. This has always been known, but it has quite recently been found that even this expedient was not sufficient fully to satisfy the excessive refinement of the Greek eye, and that the boundary line of the Doric shaft, in the best examples, was made not merely a convex line, but a part of a true hyperbolic curve, a hyperbola, no doubt, of an extremely small axis minor, but, nevertheless, a hyperbola drawn with exact mathematical accuracy. Many of you are probably well aware that, although this fact had been previously surmised by others, the ascertainment of the truth with precision has been the result of the very careful observations and measurements of Mr. Penrose, made under the auspices of the Dilettante Society. Here is an instance of the extreme delicacy and fastidiousness of Greek taste, and an evidence of the value attached by the Greeks to what probably appears to most of us to be a very trifling matter. We may, however, learn to set a higher value on a rigorous attention to such trifles, when we contemplate the mischievous results of a neglect of them. The later imitators of the Classic style saw this entasis, but, being utterly unable to feel as the Greeks felt, they presumed that all they had to do was to swell the shaft, and so they swelled it, but to such a preposterous extent that, as Evelyn quaintly observes, their columns appear to be sick of a tympany.

A similar evidence of nicety of taste is presented to us in the mathematical precision with which the Greek echinus is curved. The artists of that wonderful period were not content with an ordinary and simple curve, which might have satisfied a less sensitive taste, commencing the contour with a straight line and gradually giving the upper part of it a curvilinear form resembling that of the natural echinus. But the careful measurements of Mr. Penrose prove the curvature of the Athenian echinus to be strictly and exactly hyperbolic, as the Greek sculptor felt that his curve should be.

Now I would call your attention to another instance of the really wonderful delicacy of the Greek eye. Most students who have looked over the pages of the earliest expounder of the laws of architecture—Vitruvius, will have been sadly perplexed by the instructions given to us by him, touching the "*Scamilli impares*" in a Greek order. Much as the question has been voxed, I do not know that any expounder of the text ever satisfactorily explained or ascertained the exact meaning of those words by the aid of the plumb and level, until Mr. Penrose did so, when engaged on the minutely critical examination of Athenian remains, made by direction of the Dilettante Society. That most careful observer has shown us that the course of masonry forming the base line on which the columns of a Doric portico were placed, was studiously laid with its upper surface very slightly but appreciably convex; and though Vitruvius, on laying down this rule, does not give us the reason for it, yet there can be no doubt whatever that, like the other minute observances of the Greek masons to which I have adverted, the "Scamilli impares," which were the result of this very peculiar mode of construction, were intended to correct an optical illusion similar to that which the entasis of the column shaft was intended to correct;—thus furnishing another illustration of the extreme fastidiousness of these accomplished art-workmen. It is in like manner shown by the measurements of Mr. Penrose that the soffite of the entablature is executed with a very faint concavity. We can well understand the motive for this. Every one will have observed that, through some visual deception, any large surface of flat ceiling appears depressed towards the centre:—such an effect on the eye was sure not to have escaped the observation of Greek builders, who adopted this natural mode of correction.

I am tempted to add one other illustration. On a former occasion I pointed out to you a slight, but very delicate instance of that fastidiousness to which I have been adverting, in the faint concavity which was wont to be given sometimes to the facettes of a Doric triglyph. The motive for this concavity may be readily surmised to be a wish to render the drawing of those triglyphs distinctly perceptible, without resorting to too deep or sharp indentations, which might by their shadows have interfered with the effect of sculptured metopes, and detracted in some degree from their breadth and effect, that quality which is one of the distinctive charms of all Greek art.

Perhaps there is no lesson which those artists inculcate by their example more emphatically than that manifest love of their art for its own sake which constantly led them to take what ordinary minds might have considered superfluous trouble. The same unsparing prodigality of labour which they showed in giving to the unseen back of their pedimental statues as high a finish as the front, and the same scrupulous attention to truth in the anatomical minutiæ of their bas-reliefs, however remote from the eye, to which I have already adverted;—the same feeling extended even to the subordinate details of their masonry,—to the gargoyles in the crowning cyma of their cornices, and to the antefiæ on the eaves of their roofs,—interesting instances of which we possess in the British Museum.

We will now pass over the Roman period, which was but the dim sunset of art; and, hurrying past the still dark shades that followed that period, we will seek illustration in the best period of Mediæval art. We shall there find, that if the more refined æsthetic niceties may be wanting, there yet existed, without doubt, a high appreciation of the value of a careful attention to details.

The mouldings of the thirteenth century are of themselves sufficient evidence of the strong artistic feeling that pervaded our art at that period. While a forcible effect was studiously sought by deep undercuttings, and by a brilliant sharpness of execution, the best Mediæval artists never lost sight of the value of that breadth which had been, as I have said, the peculiar merit of Greek mouldings. Their mouldings were massed together in groups kept forcibly distinct by deep, undercut hollows, producing powerful lines of shadow

The custom prevalent in the thirteenth century, of banding the shafts of columns, is another evidence of nicety of taste. The practice was quite original, and was admirably adapted to obviate what might otherwise have been a meagre effect of the somewhat excessive slenderness of those column shafts.

Another instance of delicate perception, very worthy of observation, is presented to us in the execution of their spires. Although the Greek entasis of columns was wholly unknown in the Gothic school, a feeling exactly similar taught them to give an entasis to the spire: so delicate as to be scarcely perceptible, and yet, I believe, never wanting in the best examples.

Time will not permit me to pursue this subject much farther; but the sketch would be unpardonably imperfect were I to omit allusion to the really wonderful attention paid by the able masters of the Renaissance period to the whole subject of architectural detail. I do not mean that in the practice of those masters there was any excessive resort to ornamental detail. On the contrary, the best artists of the quatro-cento school usually aimed at producing good effects by very simple means, although undoubtedly they showed themselves to be complete masters of ornament when they thought proper to resort to it. The architecture of L. B. Alberti, of G. Romano, of Raffaelle, and others of that early and pure school, is marked by consummate sense of beauty of proportion, and of general outlines; but no masters knew better,—I believe I should say none but the Greeks knew so well,—how to enhance that beauty and to enrich those outlines, by details of highest purity and simplest character.

I may perhaps be permitted to extend my observations on the susceptibility of good taste in the minor objects of design, by referring to the subject of fictile vases.

When we regard those ancient works in the early purity and youthful freshness of the Greek style, the beauty that pervades those insignificant objects of the potter's art appears to me truly surprising. It would be difficult to illustrate the power of art more forcibly, than by contrasting the exquisite outlines of that very early Greek earthenware, with the pots and pans of this vulgar modern world. There is, perhaps, no greater manual dexterity, no more mechanical skill, shown in one than in the other; there may, indeed, be less exactness of execution in the old than in the new works; but the one has those peculiar qualities which the educated eye at once recognises as the elements of beauty, whilst the other lays claim to no attention, and has no æsthetic merit. Certainly it is a phenomenon that would be very surprising, were not the fact so familiar to us, that during the two thousand four hundred, or two thousand five hundred years that have passed since the best of those fictile works were produced—a period which comprehends the whole history of human civilisation from the period of primæval simplicity down to the vulgarities of the nineteenth century—there has been an unceasing struggle to alter, vary, and improve; after indulgence in every species of novelty, excess, and caprice, we have never succeeded so nearly in producing forms beautiful in shape and colour as when we have copied the old Greek type. Beautiful things of this nature have been found in Oriental art; beautiful in Mediæval art; beautiful, too, in the age of the Renaissance; but analyse those several beauties, and you will find that those please us most in proportion as they approach the nearest to that wonderful type.

This is not encouraging to modern invention; it is not gratifying to modern vanity; but it is true, and therefore demands our observation. At all events, it should teach us modesty, and stimulate us to respect and to study those examples which our earliest teachers have set before us. Whatever may be the cause, I think the fact is undeniable that, though the arts and sciences are usually regarded as kindred pursuits, and are supposed to be intimately associated, they are in truth widely different in their history and destiny. Science has been progressive: step by step men have advanced in the knowledge of the exact sciences as time has advanced. The step of to-day helps us on to the acquirement of a further step to-morrow; and the horizon is thus ever widening as we advance. Quite otherwise seems the destiny of art. The small objects of art to which I have been adverting illustrate this anomalous fact, and so perhaps may be said of almost every other object of design, in the sister arts as well as in architecture. Has Raffaelle yet been surpassed? Have the works of Phideas yet been rivalled?

But I must return to the humbler theme of my lecture of to-night. It is not of statues that I have to speak, but rather of the pedestals they stand upon; and, indeed, of these pedestals I have much to say. I should be pronouncing a very unmerited condemnation of sculpture were I to say that statues and their pedestals have in modern times shared the same fate. One might have expected that the same taste and talent which an artist exercises in the production of a fine statue would distinguish equally the base it stands upon. Can we admit that such has been the case? Have we, during the last two hundred years, made great progress in the art of designing pedestals? Has the work at Charing-cross been thrown into the shade by any subsequent work of like nature? Have we gone on, step by step, improving on our ancestors, in form, or in proportion, or in graceful decoration? But I am not about to enter critically into the masonic efforts of modern pedestal builders. It will be a more agreeable, as well as a more profitable, task to invite your attention to the pedestals of other times and of other countries. Few exist of Classic times; very few of them indeed are standing where they were originally placed. After barbarian violence has thrown down a fine statue, and after time or accident has buried it, its own merits or value may cause it to be disinterred. Not so, however, the masonry on which it stood, and thus we are left in general ignorance as to the exact character and proportions of Classic pedestals. We have, fortunately, in the British Museum a few examples of the highest quality of Greek art, and although the overcrowded state of our galleries there forbid the public exhibition of them, they are well worthy of your careful study. They are, it is true, of but small size and of very simple design. Indeed, it does not appear to have been the practice of the sculptors of that refined period to place their groups upon pedestals of any pretentious proportions. It would appear as if they desired these pedestals to attract notice as little as possible, so as not to divert attention from the nobler work which was placed upon them. They had usually, perhaps always, a moulded capping and a plinth, but these mouldings are kept the very reverse of forcible in their effect. Even the inscriptions on these pedestals are tenderly treated: the letters are small, regular, and uniform in size, and in form always extremely slender, and always of very moderate intaglio; presenting a singular contrast with the pompous lettering of later days.

Were it not likely to lead me astray from my proper subject, I might suggest that, analogous to this deterioration in the treatment of their inscriptions, is the style of their composition. In the best times of art these incised records are condensed in style, and severe and simple in their mode of expression. It is only in later and degenerate times that we find the lettering bold in size and violent in depth, the lines capriciously varied in their length, and the sentences "exhausting the pomp of woe" in inflated and grandiloquent words.

I would request your attention to the beautiful monument of Coleone, one of the great Venetian Condottieri, of the date of 1495. The statue by Verochio it is not my business to advert to; but the pedestal I regard as one of the most ornate, as well as one of the most elegantly-proportioned, pedestals that I can call to mind: it is a noble example of the quatro-cento style, a style of which you have so often heard me express my qualified admiration.

(To be continued.)

THE CATCHMENT BASINS OF RIVERS.

When Bramah about thirty-five years ago invented the water-closet, he little dreamt of the great sanitary and agricultural revolution he was inaugurating. We all know upon what trivial events momentous changes sometimes depend; but possibly in the whole history of our material progress no such example of this trite saying can be found than is afforded by the introduction of this useful appliance. Before its introduction the house drains were in no manner connected with the public sewers; the sewage flowed into cesspools which riddled our basements and perpetually gave forth deadly gases, which filled our houses, and killed us with fevers, while the main sewers only took off the surface drainage. They were simply the conductors of the watershed of towns, and any attempt to turn the house drains into them was resisted by the Commissioners of Sewers. The rainfall through them found its way to the river, and the sewage to the land, which was removed at stated times by a service of nightmen, as it is at present in Paris and other large Continental cities, after doing all the mischief it could to the household, and after losing as much as possible of its own virtue for the purposes of the soil. When the hydraulic appliance of Bramah came slowly into operation, the cesspools could no longer hold the largely diluted sewage, and the evil became so great that the custom arose of flushing the house drains into the main sewers. This was clearly contrary to law, but it was winked at by the authorities; it was a great public necessity, in fact, which put all old arrangements aside, and slowly the whole sewage of the metropolis was conducted into the Thames. Those who remember the river thirty years ago can remember a comparatively pure stream, up which salmon used to work to their spawning grounds. Shortly, however, its colour began to change from year to year, and at last it became so foul that, in 1859, white paper thrown into the stream was immediately blotted out by the dirty water, and the committee rooms of the Houses of Parliament became unbearable in consequence of the stench it gave forth.

Chief Justice Hale laid it down as law, that "every man was to keep his own dirt at home;" we did this, and probably should have gone on doing so until this day, had it not been for Bramah; he washed it up before our very eyes and noses in the river, and, more disgusting still, he made us drink of it; and forthwith we commenced mighty works to take it down to the ocean. But other towns higher up the valley of the Thames having acquired powers under the newly-constituted local Boards of Health, took example by the Metropolis, and transferred their cesspools into the stream, and thus commenced again the poisonous process we have taken so much trouble to abolish. Every day sewage is flowing down into our drinking water from the 800,000 persons located in the valley of the Thames above London. The gross absurdity of thus going to the expense of millions to get rid of our own sewage, that we may have the pleasure of drinking that of the fifty-three towns and villages of the upper Thames, must have struck everyone. It is quite certain that the maxim—"everyone for himself"—must in its narrower interpretation give way to some scheme for dealing with the difficulties thrown upon us by the independent action of local boards having jurisdiction over restricted areas only. The Thames valley, containing perhaps the most important elements of the problem to be solved, has attracted the greatest amount of attention.

Dr. Ackland, of Oxford, has for some time advocated the necessity of appointing some authority to control the catchment basins of rivers, and in conjunction with other gentlemen presented a memorial to Sir George Grey, two years since, with respect to the particular catchment basin of the Thames. The evidence he gives in the report before us of the condition of the river near Oxford is certainly disgusting. He states that in one place the deposits of sewage have diminished the depth of the river by 6 feet, a "disengagement of gas takes place at the bottom of the water, and large masses of black sewage which have been deposited are thrown up to the surface," masses of human ordure totally unchanged are seen floating down the river for several miles. Every year the other large towns on the Thames—Abingdon, Wallingford, Reading, Windsor, Eton, Walton-on-Thames, Richmond, Brentford, &c., are obtaining powers to drain into the Thames. Each town thinks only of getting rid of its own refuse, quite regardless of the nuisance it is creating for the other towns lower down the stream. It is quite clear that no genuine system of fluvial purification can be carried out as long as mere local interests are allowed to be consulted.

Mr. Rawlinson, the principal inspector in the Local Government Act Office, who has inspected the rivers of Lancashire and parts of Yorkshire, says (3993):—"They are fouled almost from source to estuary." The rivers Irwell, Medlock, Irk, and the Bridgwater Canal, are more offensive from sewage than the Thames. The Medlock at Manchester is covered with a black scum so thick, that birds are able to walk over it. The rivers and streams in Lancashire and Yorkshire are fearfully abused. There are river beds in those counties that are raised 10 or 15 feet by sewage, ashes, and other refuse. "There are," says Mr. Rawlinson, "bridges under which a dog can scarcely creep, and I have had evidence from inhabitants that they have driven loaded carts under these same bridges." In the neighbourhood of Birmingham the streams have been silted up many feet in the same manner. The want of some central authority to deal with the watersheds of districts is illustrated by the case of Salford. The inhabitants of this town wished to carry their sewage by tunnel 3 or 4 miles from Manchester, at an expense of £80,000, but were prevented from doing so by the refusal of other towns to co-operate. "Of what use is it," they say, "to expend large sums, when Manchester and all the other towns above will continue to foul the river?" The river at Birmingham contains in dry weather as much sewage as water. Birmingham once boasted of being one of the healthiest towns in England, but this distinction it has long lost, as its mortality is now much higher than that of the metropolis, and it always suffers from a type of fever. The river Aire, which passes through Leeds and Bradford, is as foul as the Medlock. Passengers crossing the canal in trains are obliged to shut the windows, in consequence of foul air (4115). The Clyde at Glasgow is worse even than the Thames. We might, perhaps, expect to find filth in the rivers of manufacturing towns, but it is observable that places famed of old for hygienic advantages are now being poisoned by the practice of throwing the sewage into the river. The case of Bath is particularly strong, The river Avon, near that city, is nearly a stagnant stream, and is quite poisoned from this cause, and so great is the deposit of sewage in it, that the navigation is impeded. It is not quite so bad at Bristol, as a portion of the sewage of the town is diverted into the tidal river, but the floating-harbour which runs through the old town is quite pestiferous. The perverse arrangements which obtain in many of our watering-places are very observable. In many cases the outlet of the drains is into the sea. The sewage of Exmouth passes, by an open drain, along the foreshore as far as low-water mark, which is within 70 yards' distance of the public bathing-place. At Brighton the ladies are subjected to a similar arrangement. At Southsea, again, the mouths of the sewage-pipes open close to the pier, and to the bathing-machines. The county surveyor for Somersetshire, who has paid much attention to the drainage of towns, gives a most deplorable account of the condition of some of the western towns. In the rising watering-place of Weston-super-Mare all the sewage runs into one of the rhynes or open ditches which drain the marshland of the district. The water in it is so foul that the cattle will not drink it. The river Tone is poisoned by the sewage of Taunton. The river Frome in many places is in a disgusting condition with respect to the water and the deposit along its banks. Indeed, the evidence in this respect gives most abundant proof that our rivers are everywhere being silted up by deposits of cinders and sewage, and that nobody interferes, the reason in many cases being, according to the evidence of Mr. Tom Taylor, the secretary of the Local Government Board (3897), that the persons who create the nuisance are themselves members of the local boards whose duty it is to conserve them. That it is a nuisance at common law to discharge sewage into a river has been decided, but where it is only a public nuisance there is no one to put the law into operation. When, however, direct injury is done to the property of any individual, local boards can be restrained from polluting streams by injunction. Indeed, several Boards of Health have been stopped in this manner. At Uxbridge, for instance, Colonel Tower obtained an injunction against the board for poisoning his fish in the river Coln with the sewage; at Hitchin the local board was restrained in a similar manner, and so terrified were the members at the penalties threatened by the law, that they resigned, and there is now no board in the town. At Croydon the board have suffered six or seven injunctions, and have been so embarrassed with their sewage that they have absolutely been forced to do what they should have done in the first instance, and which has made them the example to every other town in

England—they have turned it on to the land at a profit. When we remember that every farmer is compelled by his lease to consume upon his land all the manure produced upon it, it does seem extraordinary that a reverse rule should obtain when human beings are concerned. And we think we are justly open to the reproach cast upon us by Leibig, who accuses us of wilfully casting forth into the ocean those fertilising elements we have drawn not only from our own fields, but from those of Europe and the whole world.

But Croydon, we say, has solved the difficulty Bramah has slowly brought about by the introduction of the water-closet. His invention emptied the cesspools into the rivers, and for a time robbed the land, for of old their contents were returned to it in a very disgusting and costly manner. His invention now enables the sewage to carry itself on to the land. At Croydon, being stopped by injunction from throwing the sewage into the Wandle, the local board leased 240 acres of land at £4 an acre, turned their sewage upon it, and relet it for £5 an acre. Thus they make a clear profit of £240 a year, and enormous crops are got off the land, which serves as a pattern card, as it were, to the surrounding farmers of the value of sewage. Moreover, there appears to be good reason to believe, that at least another hundred acres may be profitably employed, considering the heavy dressings placed on the land by the present tenant. This would yield £340 a year, which would go in diminution of the rates. It is true that Croydon is favourably situated for the distribution of its sewage, as it stands on a height, and it can therefore be distributed by means of simple gravitation; but there are hundreds of towns in England just as favourably placed; and with this example before their eyes, of turning this heretofore considered public nuisance into a source of profit, it is really disgraceful that they should any longer pollute our rivers with it. The importance of the principle of placing entire watersheds under the control of some central board is most clearly set forth in the evidence published in the volume before us, but there appears to be a very general agreement of opinion that the functions of boards appointed for such catchment basins should be merely to supervise the action of the local boards within their district, and to enforce obedience to the law, leaving the necessary works to be carried out by the local boards alone. In short, that fear of centralisation which is ever before the eyes of Englishmen, and which has led to evils almost as great in some cases as those it wishes to avoid, is clearly evinced by all those who have given evidence upon this very important subject. The committee in their report have embodied their opinions upon it in the following paragraph:—

"We recommend that the important object of completely freeing the entire basins of rivers from pollution should be rendered possible by general legislative enactment, enabling the inhabitants of such entire districts to adopt some controlling power for that purpose; but it should include a provision for compelling local boards to render the sewage of their districts innocuous by application to the land for agricultural purposes. The case of the valley of the Thames (where the purification of the river has been sought by the expenditure of enormous sums, is, to a considerable extent counteracted by the increased discharge of sewage from towns higher up the stream) requires special and immediate attention."—*The Times.*

PROPELLING TRAINS ON LINES WITH FREQUENT STATIONS.

The following remarks upon Mr. Peter W. Barlow's paper on "Propelling Trains on Lines with Frequent Stations" (see page 48), has been addressed by Mr. W. Bridges Adams, C.E., to the editor of the 'Journal of the Society of Arts':—

"If I understand Mr. Barlow's meaning rightly—and I am by no means sure that I do—for, like the old Scottish lady, I feel "it is a sort o' presomption to onnerstan the meenister," his new proposition of working railways is by a sort of kick, or succession of kicks, to the train, not directly, as in the plan of Mr. Pilbrow (shown in the Exhibition of 1862), but indirectly through the agency of a rope, to be acted on by a steam-engine driving a pair of wheels to haul on the rope; or by Sir W. Armstrong's water column; or by some other means. But the essence of it is to put into practice the principle of the tennis or cricket ball—a sudden shock instead of a gradual movement. When we play at bowls, using the muscular force of the arm as a propeller, the bowl is a rigid block of wood, and takes no harm, because there is a gradual force applied. So also when we strike a billiard ball with a cue. But with the cricket bat or racket we use an elastic ball. With Mr. Barlow's huge bat, weighing forty tons, we must give a very powerful elastic recipient to the train, to elude the shock and prevent the breakage of the rope. We must also attain great skill in striking the blow, to be sure we drive the train-ball far enough. But even then there seems a difficulty. Mr. Barlow's objection to the locomotive is that it is gradual in attaining speed; but we can carry that speed on for any length of time when attained. On Mr. Barlow's system we are supposed to start with a given velocity, but that velocity goes on gradually decreasing, and unless there be a succession of batters, there would be the risk of stopping midway before arriving at a station. And for this Mr. Barlow's remedy is a supplementary locomotive, and of course rails for it to run on, and sidings to get out of the way. Experience in the use of ropes for traction rather points to the use of slow motion to avoid breakage; but as Mr. Barlow aims at increased speed he will have to provide such an amount of elastic action to graduate the force as will seriously detract from his incipient speed. All that Mr. Barlow can gain is the saving of the dead weight of the locomotive; but, so far as we can discern, this will be more than counterbalanced by other disadvantages. It is true that there may be more in the scheme than we have yet perceived, but as Mr. Barlow has not shown us a specific mechanical plan, and the whole is a question of mechanical structure, and his explanations have not been remarkable for lucid clearness to common understandings, we must wait in patience for further information. Mr. Chubb is quite right in saying that "the motive power should accompany the train;" but whether, under the necessity of getting rid of noxious gases, this can be accomplished by external power generated and transferred to the machine, is still a problem, whether in the form of compressed springs, or air, or highly elastic steam. If external power is to be applied in the shape of haulage, the most promising is the exhaust system of Vallance, a variation of which is now being experimented on by Mr. Rammell. If wire saucers in the shape of sheaves were used to carry a rope in the tunnel, as on the Blackwall, the noise would be something fearful. Train resistance by gravity, mechanical friction, and atmospheric impediment in the tunnel, up the gradient of 1 in 100, is stated by Mr. Burnett to be 66 lb. per ton. If this resistance could be reduced there would be more advantage than by Mr. Barlow's plan. Supposing the ordinary resistance up 1 in 100 to be 40 lb. per ton, there is 26 lb. surplus, arising from atmospheric resistance and train friction, and it is worth while considering how far the latter may be reduced. Reducing resistance is equivalent to reducing the consumption of fuel and the production of noxious gas. Practically, so long as the Great Western and Great Northern are to run ordinary engines over the Metropolitan lines, the only question worth considering is, how to prevent the destruction of rails and tires."

Notes of the Month.

Fall of a Warehouse at Shad-Thames.—At Butler's Wharf, on the south side of the river below London-bridge, a new block of buildings only very recently completed, and upwards of 100 feet in height, 140 feet in width, about 70 feet in depth, containing four floors, with iron girders and supporters, and fireproof throughout, gave way, and the entire front of the building fell into the river. Happily there was no one in the building at the time of the occurrence. As to the cause of the accident, it is stated that a large quantity of rice had been recently stored in the third floor, but whether the iron ties had given way, or the brickwork was insufficiently set, does not appear. Owing to the influx of business, the firm were compelled to warehouse cargoes of vessels before the building was actually completed. Indeed, there were masons and bricklayers still engaged on it at the time of the accident. A loud cracking was heard in the river frontage wall, and on the men looking upwards they saw the floors bulging outwards, and succeeded in getting into the street, when the whole fabric fronting the river fell into the water, bringing with it several thousand bags of rice. The land side of the structure remains entire. The excessive weight on the raw structure, no doubt, caused it to give way.

The Coal-tar Colours.—The trade in coal-tar dyes, which began in 1860, continues to expand, amounting probably to from a quarter to half a million annually. The colours are magenta, various shades of blue and violet, purple, yellow, orange, and green. The dyes are sent from London to Lancashire and Yorkshire, and other places, to be used in the preparation of silk and cotton velvets, printed calicoes, delaines, merinoes, finished cottons, silks, ribbons, flannels, and fancy and flannel shirtings. An export trade is beginning to China and the United States, the dyes being sent in their solid form to save freight. It is said that several thousand pounds are annually spent in defending the patent.

Public Works of Art Abroad.—A large new church, to be called the Eglise de la Trinite, is being erected at the northern end of the Chaussee d'Antin, in Paris; it is a large and elegant structure, in the prevailing style—that of modern French Renaissance; for the decoration of this church no less than eight-and-thirty artists have received commissions: these include the painters, Barrias, Emile Levy, and Paul Balze; and the sculptors, Guillaume, Cavalier, Crauk, Loison, Doublemard, Pierre Hebert, Frison, Armand, Fesquet, Chatrousse, Dantan junior, and Denechean. Much of the work done is of course exterior ornamentation, but the amount of commissions is set down at nearly £20,000.—Another church, that of St. Augustin, in the new Boulevard Malesherbes, leading from the Madeleine to Batignoles-Monceaux (where a magnificent quarter is growing up on the little Auteuil railway, which skirts the south-west quarter of the town, and on the land belonging to M. Periere and the Credit Mobilier) is approaching completion, and is being decked inside and out with statues, groups, and sculpture of all kinds.—The rage for public statues is most remarkable as well as satisfactory: amongst others, we may mention one of Las Cases at Laveur; another in Dauphine, of the Chevalier "sans peur et sans reproche," Bayard; a third in Normandy, in honour of Richard Lenoir, the famous manufacturer, after whom one of the new boulevards in Paris has been christened; one at Cognac, of Francis I.; one in Corsica, of the Duc de Padone; another at Florence, of Dante; and lastly, one of Rossini, a living celebrity, at Pesaro.

Photographic Maps.—A map of the town of Grenoble and its environs, embracing twenty square kilometres, has been produced with the aid of the camera in a very short space of time. The immediate object in view is the obtaining correct topographical profiles for military purposes, and consequently the means of placing an attacking force comparatively out of the reach of danger; but maps showing the undulations of the land are of too evident utility to require any special application to illustrate their value. The map in question is made to a scale of one in five thousand, and was entirely produced in Paris from twenty-nine photographic views, taken from eighteen different points by Captain Javary. The stations selected were partly on one side of the river Isere, and partly on the other, and it is believed that not a single accident of the outline has been missed. The extreme elevation of the ground on the right bank of the river is more than three thousand feet. The shortest distance at which a view was taken was about a thousand yards, the greater part were at fifteen hundred yards, and some few as distant as four thousand five hundred. It is stated, on the authority of M. Laussedat, with whom the plan originated, that fitting of the levels is such as could not have been produced by any other known method of expeditious military reconnaissance. The views were taken by two lenses of different focal lengths, namely, one of 50 centimetres, the other of 27. The former was employed for tolerably large representations and objects at a distance, or where it was found necessary to take special notice of details, and the other, which took in a field of 60°, for the shorter distances. The photographic operations only occupied about sixty hours, and the subsequent preparation of the map two months.

Electric Bells and Fire Indicators.—Mr. Sax has perfected an arrangement by which a bell is rung by the electric current, and at the same time a disk is brought to view, showing from which room the signal is sent. It consists essentially of an electric bell, which is placed in a situation where it may be seen by the persons whose attention it is wished to call. Near this is suspended the indicator. In the room or rooms from which the messages are to be forwarded, several buttons are placed against the wall; these correspond in number with the indicator; on pressing one of these buttons with the finger, the bell, however distant, is rung loudly, and a central red disk makes its appearance. It is obvious that if the press-buttons are situated in different rooms, the attendants, seeing the numbers marked on the indicator, are at once made aware from whence the signal proceeds. If desired, the whole of thr press-buttons may be placed in one room, and made to signal different messages; thus, instead of the red disk, the name of the person or article required may be shown at the apertures of the indicator. For example, from the bar of an hotel, the waiter, ostler, boots, or chamber-maid, &c., could be called as required. The bell continues ringing so long as the button is kept down. In addition to the multifarious uses to which this indicator, as thus constructed, could be applied, it may readily be made available as a fire indicator, and this is effected by a modification of the press-button; this contains a metallic thermometer, which can be set to any temperature desired; and when that degree of heat is exceeded, it makes the contact, completes the electric current, and causes the bell to ring violently so long as the high temperature remains.

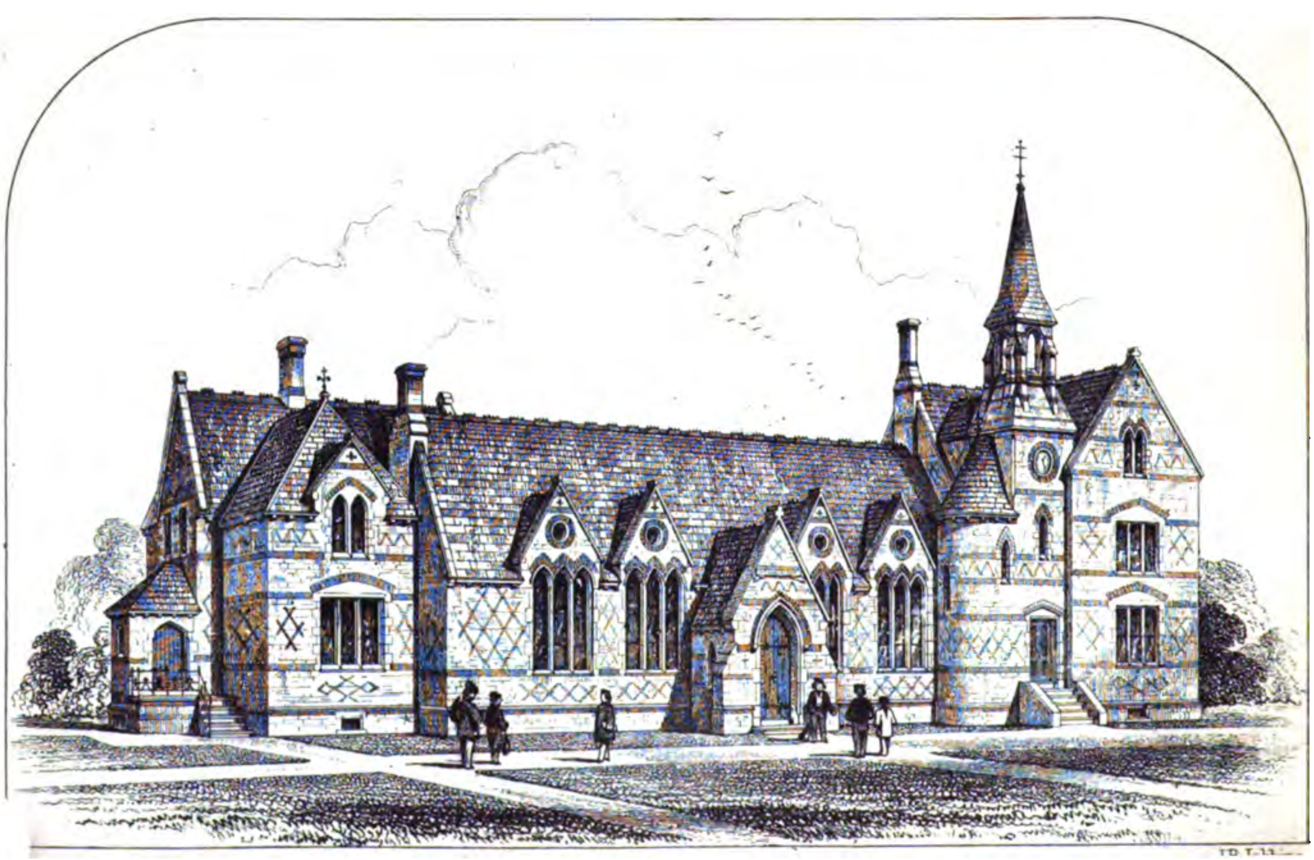
Obituary.—It has been remarked that the past year was a fatal one for artists and men of science on the Continent. Certainly the list of the departed is long and melancholy. France has lost from the ranks of art the following eminent painters:—Alaux, member of the Institute, and formerly director of the French School at Rome; Hippolyte Flandrin; Du Bufe, the elder; Allard, assassinated by one of his models at Rome; Menissier, killed by a fall from the scaffold on which he was working in the church of Saules; Roehm, Mathieu Rivoulon, Pottin, Barbier, Besson, and Leopold Lobin, director of important stained glass works at Tours; the sculptors, Louis Brian, Aristide Husson, a pupil of David d'Angers, and author of a large amount of busts and decorative sculpture; Christophe Featin, a clever modeller of animals: and Justin: the architects, Lusson, formerly engaged on public works in Paris, who has left his collection of drawings and plans to the Museum of Mans; Menager, who won the Grand Prize of Rome at the early age of eighteen, and executed many public works; Azemar, the designer of some fine mansions in Paris; Boulle, of Rennes; Querry, of Moulins; Segretain, the restorer of many fine churches in the department of the Deux-Sevres; Pellegrini, of Chambery, who built the baths and casino of Aix, and whose death is said to have been hastened by the vexation caused by the loss of all his plans, drawings, and sketches, in the fire that consumed the theatre of Chambery; Jules Gagniet, a well-known illustrator; and the engravers, Achille Lefevre, who exhibited great talent in reproducing the works of Raphael and Coreggio, one of his last productions being an engraving of the "Antiope," ordered for the chalcographic establishment attached to the Louvre; Deschamps, of Marseilles; and Godard, engraver on wood, and conservator of the Museum at Alençon. The French Institut, besides Alaux and Flandrin, mentioned above, lost Ampere, Clapeyron, A. Garnier, Hase, Arnaud-Lefebvre, and Admiral du Petit Thours. Amongst savans may be mentioned Professor A. Cochet, chemist; A. Digot, author of the "Archæological History of Lorraine," twice crowned by the Academy; Dinaux, archæologist; and Savalle, inventor of the well-known apparatus for distillation which bears his name. The following are amongst the most notable names in the obituaries of other countries:—The Marquis Costa de Beauregard, of the Imperial Academy of Savoy, and the Turin Academy of Sciences; Dr. Gerling, director of the Masbourg Observatory; the Greek savant, Bona; Professor Casper, of Berlin; Franklin Bache, the great grandson of Benjamin Franklin; Peretti, the Roman chemist; Rudolphe Wagner; Barnontz de Jassy; Hohenegger, the geographer of the Carpathian mountains; the learned Dane, Charles Rafn; Struve, the Russian astronomer; the traveller Junhung; the Hebrew linguist, Rabin Sachs, of Berlin. Amongst painters, Germany lost R. S. Zimmermann, of Bavaria; Belgium, Gustave Pierron, Henri Julien de Stoop, of the Academy of Brussels, and Charles Robert, killed while hunting; and Switzerland, the celebrated landscape painter, Calame, the illustrator of the Upper Alps, famous also for his etchings and lithographs. Belgium has also lost the architects, Roeland, Professor at the University and Schools of Art, who built the Palais de Justice, the University, the theatre and casino of Ghent, and an immense number of hospitals, churches, and other public buildings, in various Belgian towns. Rome lost, amongst other artists, Rafaelle Castellini, Director of the Mosaic School attached to the Vatican, and who executed the wonderful works, the "Sybile de Cumes," after Domenichino, and "Saint Jeane Baptist," after Guercino, which appeared at the Great Exhibition of 1851, and now are at the Tuileries.

Cuffley and Horton Archts
now. Cuffley, Horton and Bridgford.

J R Jobbins

TRINITY CHAPEL, SOUTHPORT.

The Gift of Mr. John Fernley.



TRINITY WESLEYAN CHAPEL AND DAY SCHOOLS, SOUTHPORT.

(With an Engraving.)

The Chapel and Schools which form the subject of our illustration, were opened for divine service on the 15th September, 1864, the foundation stone having been laid on the 28th of May, 1863. They have been erected through the liberality of Mr. John Fernley, who has defrayed the whole cost, and neither pains nor expense have been spared in making the edifice perfect in every respect; the result being a chapel which, for chasteness and excellence of workmanship, has perhaps no rival in Methodism. The style is the Early Lancet, and the building has been erected from the design and under the superintendence of Messrs. Cuffley and Horton, of Manchester (now Cuffley, Horton, and Bridgford). The plan comprises clerestoried-nave and aisles, transepts, and apsidal chancel, with a vestry on each side, with a tower at the north-west angle, and a porch on south side, and a chamber for heating apparatus under chancel. The exterior is executed in Burnley-wall stone and Houghton ashlar, and the interior arches, labels, and window dressings generally of Houghton stone. The total interior length is 114 ft. 6 in., width across nave and aisles 57 feet, and across transepts 77 feet. The nave arches are supported on circular polished Peterhead granite columns. Polished serpentine marble shafts, with richly foliated capitals and corbels carry the principals of chancel, the roof being panelled for decoration. The whole of the roofs are boarded, and all the timber and boarding exposed. In the nave and transept the roof is ceiled across at the collars with pierced quatrefoiled boarding running down the centre, and communicating immediately above with a wood tube, for the purpose of ventilation.

A double principal, filled in between with quatrefoiled boarding, and carried on coupled marble shafts, as before described, marks the division of nave and chancel.

A distance of 18 feet at the west end is arched off from the nave for the use of the choir and Sunday-school children, and arched recesses are formed on each side for the reception of the organ, the organist playing from his seat in the centre of the choir at the front. The whole of the pewing is executed in pitch pine, and is calculated to seat 775 persons, inclusive of children. The whole of the windows have been filled with stained glass, of chaste geometric design, by Messrs. Edmundson and Son, of Manchester. The wrought-iron gates, and other ornamental iron-work, as also the gas lighting, have been executed by Messrs. Skidmore.

The works have been carried out by the following contractors, namely:—Stonework, Messrs. Ellis and Hinchcliffe, of Manchester; the brickwork, by Mr. Riding, of Southport; warming apparatus (hot-water principle), by Mr. Wilson of Manchester; and the rest of the work by Messrs. Bowden, Edwards and Forster, of Manchester; Mr. Ogg being the clerk of the works.

Trinity day-schools, Southport, by the same architect as the chapel, are in immediate connection with the grounds of Trinity Chapel and minister's residence, and, with the offices and playgrounds, occupy about 3040 square yards. The principal front is towards Talbot-street, and comprises the infants'-school, 39 feet by 20 feet, with class-room attached, and on each side are the schoolmaster's and chapel keeper's residences respectively. In the rear of the infants'-school is the mixed juvenile school, 56 feet by 30 feet, with class-rooms, cloak-rooms, and lavatories. Red brick, with stone dressings, relieved by blue brick diapering, has been the material used. The roofs are ceiled across at the collars, for the purpose of ventilation, and plastered between the rafters, which are wrought and stained.

THE COMPULSORY SALE OF LAND REQUIRED FOR PUBLIC UNDERTAKINGS IN ENGLAND.

(Continued from page 56.)

Lands in Mortgage.—The promoters may redeem the interest of any mortgagee in such lands as they require, whether they have already purchased the equity of redemption or not, or whether the mortgage affects such lands, solely, or jointly with other lands not required. To effect this, the promoters must pay, or tender to the mortgagee, the principal and interest due, and the costs and charges, if any in respect of the mortgage; and also, (if they require immediate possession,) six months' interest in addition to that already due; otherwise they must give six months' notice of their intention to pay off the incumbrance. On payment of the amount the mortgagee is to convey his interest to the promoters, or as they may direct. Should the amount of principal, interest, and costs exceed the value of the land, or if a part only of the mortgaged lands be required, the value and the compensation to be paid is agreed, or determined as in other disputed cases, between the promoters, the party entitled to the equity of redemption, and the mortgagee; and the amount so determined paid to the mortgagee in satisfaction of his debt so far as it will extend. The mortgagee must then convey the whole of his interest in the lands to the promoters. In any case, if the mortgagee make default in conveying his interest, the money may be deposited and a deed poll executed, with right of possession to the promoters as before described. This does not affect the rights of the mortgagee against the mortgagor in any remedy for the balance of the debt, other than the possession of the lands.

If in the mortgage deed a time has been limited for paying off the debt, and the promoters require the mortgagee to accept payment before the time so limited, they must pay the costs of re-investing the sum so paid off. If the interest secured by the mortgage be higher than can be reasonably expected to be obtained on re-investing the principal at the time of it being so paid off, the promoters must pay to the mortgagee compensation, to be agreed or determined in respect of his loss, by the mortgage being so prematurely paid off.

Rent Charges and Leases.—Disputes as to the compensation to be paid for the release of lands, subject to rent charges, are to be settled as in other cases. If a part only of lands subject to a rent charge is required, such part may be released, and with the consent of the owner, the remaining lands, if of sufficient security, may be exclusively charged therewith, or an apportionment of the charge may be made by agreement between the owner, the party entitled to the rent charge, and the promoters, or if they do not agree, it is to be settled by two justices.

If part only of lands comprised in a lease for a term of years unexpired is required, the rent is to be apportioned between the lands so required, and the residue, either by agreement between the lessor, the lessee, and the promoters, or by two justices on application to them; and after such apportionment the lessee is liable only to so much of the rent as is apportioned on the lands not required; but all covenants of the lease, except as to the amount of rent, are to remain in force with respect to the land not required, as far as they will apply.

Any person claiming to be compensated for a greater interest than as tenant at will, must produce his lease or evidence thereof; and if after notice in writing from the promoters it is not produced for twenty-one days, the claimant is to be treated as a yearly tenant.

Limit of Time for exercising Compulsory Powers.—The powers granted for compulsory purchase cannot be exercised by the promoters after the time prescribed in the special act, and if no period is prescribed, not after three years from the passing of the special act. If, however, the promoters have entered upon any lands which they were authorised to purchase, and which are permanently required for the purposes of the undertaking, and it appear that they have, through inadvertance or mistake, omitted to pay or make compensation for them, the promoters may remain in possession of the same whether the time limited shall have expired or not, provided that within six months after notice, and proof of his title shall have been given by the claimant, the promoters pay to him full compensation for such interest. The compensation to be paid in these cases is to be assessed on the basis of the value of the lands at the time the promoters entered into possession, and without regard to any improvements which may have been made since that time, or in consequence of the construction of the works. If the promoters dispute the title of any such claimant to the interest claimed by him, the costs of any legal proceedings which the claimant may incur in proving his title, are to be paid by the promoters if the result of the inquiry is in favour of the claimant.

Surplus Lands.—It has been before stated that the promoters have no power to purchase, compulsorily, more land than is *bonâ fide* required for the purposes of the undertaking. The intention being to prevent the promoters becoming land speculators, at the expense of the existing owners, by buying up more land than they actually require—in the neighbourhood of an intended railway station for instance—and then selling the same at a profit, which would otherwise go into the pocket of the original owner. Often, however, the promoters under the provisions of their act by agreement, or under a requisition from the owner under the various circumstances before alluded to, become possessed of a quantity of property beyond that so required for the purposes of the undertaking. They are not allowed to keep in perpetuity even this which has been thrust upon them. If no time is prescribed in the special act for the sale, then within ten years after the expiration of the time limited by the special act for the completion of the works the promoters must absolutely sell and dispose of all such superfluous lands, and in default thereof all such lands vest in and become the property of the adjoining owners.

Before the promoters dispose of such surplus lands they must, unless the lands are situate in a town or are built upon or used for building purposes, offer to sell them to the person then entitled to the lands from which they were severed; or if he refuse to purchase, or cannot be found, the like offer must be made to the persons whose lands immediately adjoin those proposed to be sold, in succession if there be more than one, in such order as the promoters think fit.

If any such persons desire to purchase they must signify their intention to do so within six weeks after the offer of sale, or they lose their right of pre-emption. If the price to be paid for the lands cannot be agreed, it is to be settled by arbitration. The costs of the arbitration are in the discretion of the abitrators. If the right of pre-emption be not exercised or claimed within six weeks, some person not interested must make a declaration that the offer was made and refused, or not accepted, or the persons entitled were out of the country, or could not be found, or were incapable of entering into a contract, as the case may be; and the promoters can then sell the lands to any person, by auction or private contract, at such price as they may think fit.

The promoters are to keep at their principal office a copy of their special act, and if the works (as a railway or canal) are not confined to one town or place, they must also deposit a copy with the clerks of the peace for the several counties into which the works extend, and must permit all persons interested to inspect the same and take copies or extracts.

"The Lands Clauses Consolidation Acts' Amendment Act, 1860," (23 & 24 Vict., cap. 106) extends the power of commuting for a rent charge the purchase money or compensation to be paid in respect of any lands to all persons interested, whether they are under disability or not. If the promoters purchase lands in consideration of a rent charge their powers of borrowing are to be reduced by a sum eqnal in amount to twenty years' purchase of the rent charge so agreed to be payable. The provisions of the Lands Clauses Act are by this act extended to enable the Secretary of State for War, and also municipal corporations, with the sanction of the Treasury, to purchase lands under its powers for purposes of a public nature.

P.

(To be continued.)

THE INTRODUCTION OF COLOURED BRICKS, ETC., IN ELEVATIONS.*

By Henry A. Darbishire.

The following brief remarks have been prepared with the hope that the interest of the subject to which they refer will be received as sufficient excuse for their intrusion upon your attention, and that they will give rise to a discussion, which shall yield much valuable matter for the guidance of all who are practically engaged in employing coloured bricks as an effective and inexpensive architectural enrichment. They have been suggested at intervals, during long railway journeys, when reading has become wearisome, and a good look-out of window has relieved the monotony of confinement. By a good look-out, I do not mean a vacant stare at nature in an uncomfortable state of perpetual motion, but a wide-awake look-out when the senses are alive and active, and the mind is both ready and willing to receive impressions of objects as they are presented in rapid succession. It must be admitted that a transit of forty miles an hour is not favourable to accurate observation of details, but leading features can be easily distinguished, and a traveller can determine, without effort, the outline of a mountain, the foliage of a wood, or the form, general proportions, and colour of a building. If his observations be confined to buildings, I think he will lack neither amusement nor instruction. Among many other things, they will teach him to criticise their merits and imperfections by the same rules which influence the criticism of that large and important section of the community, the general public; for they will reveal to him only those features and characteristics which are most prominent, and therefore most apparent and intelligible to critics who are not fully acquainted with the laws and practice of architecture.

It becomes an object of no slight importance, to discover, if possible, how public gratification, or in other words, favourable public opinion, may be secured and increased by the adoption of means which are easily accessible. To accomplish this object it is necessary in the first place, to ascertain with tolerable accuracy, what features in a design are most easily comprehended and approved by an unprofessionally educated observer, and in the second place to discover the means of rendering them easy of adoption; the first, as I have already said, I believe can be done without much difficulty by a rapid survey of the buildings which troop past any railway carriage window; but the second, viz., of bestowing upon them prominence and effect by the employment of simple and economical expedients being much the harder task, can only be undertaken, with any hope of success, by those who have been actually employed in carrying designs into execution. As we have not time to devote attention to more than one of these features, we will take the most conspicuous, viz., colour; not its redness, or blueness, or greenness, but its blackness and whiteness, its light and its shade, its lights and its shadows, produced by the exposure of its various and irregular surfaces to the fair light of day. Admitting this interpretation of the word as acceptable, the importance and influence of colour cannot be denied. How endless are the resources, how lavish the means employed to secure it; how exquisitely varied and beautiful are the results which it is powerful to obtain, and how miserable the effects of failure from a misemployment of its coveted agency! To produce colour the attention of thoughtful minds has been occupied, to a greater or less degree, from the earliest ages. Ochres and chromes first tried to accomplish the feat, whose chief glories were reserved for Greeks and Romans and those great workers in Gothic art who succeeded them. To what other source than to the love of colour and a high appreciation of its value can we trace those beautiful architectural mouldings and enrichments which our forefathers and foreworkers have bequeathed to posterity? The waves of the sea, the bones of the human body, the great sun itself, they lovingly studied, and learnt from their delicate outlines to combine the cyma, astragal, and circle into forms so bold and yet so delicate, so complex and yet so simple, so various and yet so uniform, that "they weary never, but are for ever new." Is it possible that the value and importance of colour in architectural works can be over-estimated by those who care to observe its effect in any of our principal squares or thoroughfares? Do not these afford sufficient proof, if proof were wanting, that its power of bold assertion can destroy all unity and proportion in those attributes which are less obtrusive, but which are nevertheless quite as deserving of consideration? Our streets and squares are literally striped with every conceivable tint the painter's brush can give them. Blacks and greys in endless variety, alternate with whites, yellows, or buffs, according to the fancy or finances of their occupiers, and by their prominence mutilate continuous lines of detail, as effectually as if they were actually broken and disconnected by difference in their design. How few persons would believe that the building on the west side of Trafalgar Square, for example, is really a uniform and regular composition. That portion which is occupied by the College of Physicians is so black, and the remaining two-thirds, belonging to the Union Club, is so white, that none but a critical professional observer would detect any similarity in the two divisions. To all appearance they are separate buildings, and if either of them were burnt down or removed a hundred miles away, the other would remain unaffected by the loss. If it be necessary for a building, or a group of contiguous buildings to be coloured, the colour should be limited by the lines of their architecture, and subject to the conditions which they prescribe, as it is on

* Read at the Royal Institute of British Architects.

the Continent, and especially in the towns on the Mediterranean, where the streets are full of colour, as varied, certainly, and very much brighter than they are here. There colour is subservient to the architecture, while here it defiles and overcomes it.

In large buildings were both space and means are liberally supplied, bold projections and deep recesses distinguish, by well defined masses of light and shade, the most prominent parts of the design from those of inferior importance, and these again are relieved by rich and delicate details radiant with lines and intricacies of light, which mark out the general proportions and subdivisions of the whole. Basements and entablatures, string courses and cornices, with all their attendant accessories of granite columns, marble capitals and finely polished surfaces upon which the sun-light loves to linger, all contribute their bright and varied gifts of colour so cunningly disposed, as to redeem the plainest work from monotony and the most elaborate from becoming dull.

In ordinary buildings, by which I mean buildings of ordinary size, built of ordinary materials and appropriated to ordinary purposes, the case is altered. For them space is usually confined and funds too often scarce. Bold projections and deep recesses give place to uniform and unbroken surfaces, polished stone to common brick, and richly clothed moulding to naked arrises. What then becomes of colour? does it too take flight and leave all barren? Not in the least. Railway observation teaches that, in ordinary buildings, and especially in those of the most diminutive proportions, colour bounds to an extent almost bordering on monopoly; and not merely colour as hitherto defined, blackness and whiteness, light and shade, but rainbow colour, green, blue, red, black and purple, distributed into every conceivable pattern, and subdividing every surface to which it is applied into as many squares and parallelograms as a Kidderminster carpet. As this colour is literally applied colour, and is not originated by skilful combinations of the various associated portions of the design itself, its independent obtrusiveness especially arrests attention and lays claim to a few words of consideration.

It is generally produced by variegated bricks and tiles of beautiful manufacture, and often of careful and elaborate design obtainable at comparatively small cost, and easily worked in with building materials of the coarser and more ordinary descriptions. These desirable qualities necessarily render them popular, but at the same time subject them to the liability of being employed by the unskilful and unconscientious designer as available agents for obtaining what may be called "ready-made" effect, and relieving him of a load of inventive and thoughtful labour. This constitutes the chief danger by which their attractions are surrounded, and offers the readiest explanation of the cause of that disappointment which appears to be inseparable from their employment as architectural decorations.

To explain my meaning more clearly, and as I have purposely avoided reference to drawings, I will take an example from the most numerous class of ordinary buildings, which may be called the diminutive domestic class, and which includes that model of perfection which the agents delight to advertise as "a most desirable villa residence," possessing all the advantages and disadvantages of the architectural sliding scale, which begins with a palace and ends with a cabin.

As we are not concerned with the interior arrangements of a vestibule, hall, double drawing room, dining room, breakfast room, billiard room, library, conservatory, observatory, and boudoir, or with the surrounding attractions of terraces, shrubberries, gravel walks, fish ponds, plantations and flower beds, with gods, goddesses, urns and fountains interspersed over the entire domain, which covers at least half an acre in extent, our attention must be confined to the external appearance of the building itself.

The principal elevations are generally about 35 feet in length, and of a proportionate height. As plain surfaces are considered objectionable, the wall spaces are crowded with lozenges, crosses, and unintelligible diagrams of every description, and are broken up by gables, gablets, bow windows, bay windows and oriels, porches and glazed colonnades, till a square foot of repose is sought for in vain. The dissecting process is extended to even the smallest details, and so effectually are these subdivided into minute and inappreciable parts that plinths, strings and cornices lose their value as distinctive features, and are lost in a confused and unintelligible conglomerate. The confusion necessarily arising from this dissection of small wholes into still more insignificant parts, if not solely attributable to the employment of coloured bricks, is very materially assisted by them. Assuming that they are similar to common bricks in every respect except colour, and, perhaps, fineness of texture, the very uniformity of their dimensions and the variety of purposes to which, with its drawback, they are applied, renders it impossible for them to accomplish successfully all that is expected from them. It is not because they are valueless, but because their value is not properly estimated that they so often produce such unworthy results. In small buildings of the class which has just been described it will be found, almost without exception, that if they are used as mere flat facial decorations they are so disposed as to partition the wall spaces into as many squares as a chess board; if they are employed as angle quoins, they are stepped in blocks so large as to reduce the apparent height of the elevations; if they are introduced as enrichments to door and window openings, they interfere with their proportions; if they are substituted for moulded bands or string courses, they are either coarse or unintelligibly minute; if they are employed in the construction of arches, they destroy the continuity of line upon which the chief beauty of the arch depends; if they are inserted among the interspaces of cornices, extraneous entablatures, or other similar groups of mouldings, they perplex their shadows instead of adding to their significance and depth: thus it may be fairly admitted that unless their introduction be undertaken by those who are aware of its difficulties and are able to overcome them by the power which sufficient knowledge and well educated taste alone can supply, they cannot fail to create disappointment and regret, and cause their entire absence to be more commended than deplored.

It may be well, before proceeding further, to ascertain how far the foregoing assertions are justified by facts, and *First*, as to the employment of coloured bricks, &c. as facial decorations, by which is meant their arrangement upon flat and uniform wall spaces into various fanciful devices, obtained by colours in contrast with the wall itself.

If a wall be broken up by several openings or projections the interspaces become numerous, and consequently of limited size. These interspaces are the principal divisors of a building, and as they define not only its linear proportions but receive those shadow lines which no rule and compass can control, and which vary with each passing moment, it is most desirable that their distinctness be acknowledged as an attribute of value, and preserved inviolate. Lines of demarcation, however boldly expressed upon paper, too often vanish like shadows before the sunlight, which recognises no lines but those determined by the substantial realities which oppose it, and whose opposition creates a progeny of new lines full of beauty and variety, and from their extreme delicacy demanding the most careful protection. Confused wall spaces will cause confused shadows, vague and undefined, void of depth and transparency, and robbed of all the clearness which renders their delicacy so attractive. It may occasionally happen that the sizes of the wall spaces may vary considerably in the same building, and that some may be so much larger than others and so much more exposed, as to render it desirable to relieve them by introducing monograms and other devices of a similar character. When this is the case the colour of the wall should be first considered; if it be dark, the devices should be darker; if it be light, they should be lighter; for instance, in a red wall the devices should be executed with black bricks; if it be a wall built with the common yellow stock bricks, best known in London, they should be executed with Suffolk or Bath bricks, so that in neither case may they present too glaring a contrast. Generally, however, wall spaces should be as plain and unconspicuous as possible, and it requires but little art to render them so.

Secondly. As to their employment as angle decorations or quoins. It too frequently happens that the desire to employ coloured bricks in situations generally assigned to stone, causes the uniformity of their dimensions to be overlooked or disregarded. This is especially noticeable where they are introduced as angle quoins, where they are massed together in blocks fourteen or eighteen inches long, by twelve inches in height. These proportions are usually observed because they work well with the general construction, but they are too irregular for beauty, and so large as to give a false scale by which to estimate the size of the elevation. Usually the bricks are of a lighter colour than the general wall face, and this prominence renders their disproportion more apparent. In buildings of moderate height they assume the appearance of steps, by which the eye is enabled to ascend from basement to roof by gradations so easy and regular that it has leisure to measure each foot as it rises, and refuses to accept any assertion of size but that whose accuracy has been fairly tested by its own observation. This, it must be allowed, presents a strong argument against their employment as quoins, but it is not so serious as to justify their banishment from this office. If they be only treated as bricks, and not as representatives of stone, and if their colour be selected with judgment, they will prove both ornamental and useful assistants. In order that they may avoid the offence of affecting to be that which they are not, they should be joined like the rest of the work; but if they differ from this in colour, as they may do, the mere alternations of header and stretcher will present a poor and meagre appearance, unless a closer be introduced to render the regularity of the sub-division less evident. Their colour should harmonise with that of the general wall face, and not present any striking contrast to it. Like the ornamental devices already mentioned, they should be darker than the dark wall and lighter than the light one, and so avoid the stepping-stone appearance which their uniformity in height might be apt to suggest. Before leaving the subject of quoins, we may observe, that wherever coloured bricks are employed at the angles of a building their value may be considerably increased by rounding their external arris into a quirked bead, so that the sharp cutting line, which offends in all new work by its rigidity, may be softened and refined.

Thirdly. As to their employment as enrichments to door and window openings; not very long ago I was required to execute a design, in which it was considered important that the door and window openings should be ornamented with red bricks. The walls were of common yellow stock bricks, and the colour selected for the door and window jambs and arches, of a modest, inoffensive red. For economical reasons Suffolk or Bath bricks were out of reach. When the building was finished, the critics appeared, and as a matter of course expressed their opinion without reserve. None of these were unkind or unjust, but there was one whose criticism was too pertinent to be forgotten. After taking each portion of the work in its turn, he drew attention to the '*opthalmic*' appearance of the doors and windows. The next time I saw them, their affliction was apparent, and my attention once roused, I soon became unpleasantly aware that mine was by no means the only building suffering from the complaint, and that opthalmia, proceeding from the same cause, abounded. Consideration of its prevalence led to the conclusion that, if coloured bricks be employed as enrichments to door or window openings, they must either be limited by definite lines, maintaining proportions which have relation to the openings themselves, or when these cannot be obtained their limits must be left so vague as to prevent their suggesting that proportion was attempted, but could not be secured owing to the difficulties inseparable from its accomplishment. We need not be reminded that if a door or window receive any kind of decoration beyond its clear opening the proportions of the decoration will materially affect those of the opening itself, and especially if the colour of the decoration be conspicuous. Coloured bricks are, for this reason, most unmanageable. Unless they are purposely moulded or cut for adaptation, like stone, they ought to be applied only to those openings which are multiples of their own dimensions. As moulded and cut bricks are not those under present consideration, the established length, breadth and thickness cannot be set aside; and while admitting the efficacy of the limits assigned to each of these, for the purposes of construction, the doubt arises as to how far they are qualified to supply the elements of good proportions. This doubt is strengthened when we consider them—

Fourthly, as substitutes for moulded bands and stringcourses. Three inches, the accepted thickness of a course of common brickwork, may be termed the small divisor of the vertical subdivisions of an elevation, and any bands which may be introduced to give these subdivisions prominence, must necessarily be multiples of three inches. For the bands of low buildings three of these divisions will be sufficient if they are flat; but when their outline is varied, four at least are required, as their increased projection renders it necessary for the uppermost course to be weathered. Unless the band be of considerable length its depth of twelve inches will appear disproportionate, for, supposing the weather-course consist of headers, which is not desirable, and it projects four and a half inches from the face of the wall, which is as much as it should do, but little variety of shadow can be obtained below it, not sufficient, certainly, to redeem it from heaviness. The distribution of a twelve-inch band, which was often adopted by the old builders in brick, and which appears to be the simplest and most effective, is three inches for the weather course; three inches for the ornamental course, either saw-tooth, billet-mould, or dentils, and underneath a plain course of six inches to receive their shadows. In modern works, the third course is frequently flush with the face of the wall, and the lowermost course projects two and a quarter inches so as to serve as a necking. This arrangement possesses the advantage of giving to the ornamental course the benefit of its entire projection, but at the same time it divides the twelve inches into four equal lines, each of which is only three inches in breadth. To avoid the difficulties attending the unalterable limitation of three inches, another plan has been adopted, which few will allow to be very successful; it is that of inclosing nine-inch square variegated tiles between two fillets of cement, each fillet being an inch and a half in breadth. There are instances (and one building in the city is especially noticeable) where cement has been most effectively and almost legitimately combined with the brickwork so as to serve all the purposes of stone; but these are so rare that their exception only proves the rule, that the employment of cement in brick buildings ought to be carefully avoided. With regard to tile decoration, it may be said that, unless its design consist of simple, well defined forms, expressed by well contrasted positive colour, it will have a weak and unmeaning appearance. The more complex, and it may be the more delicately beautiful, the design when close to the eye, the more ineffective and disappointing will it become when removed from it. Tile bands or strings are, moreover, generally so refined looking, that they seem unable to accommodate themselves to the requirements of their coarser neighbours. They look isolated and out of place on a bare brick wall, and suggest the unsatisfactory idea of being applied without sufficient purpose. This impression is strengthened by their tints being of a character so entirely different from that of the finest coloured bricks. The eye will follow colour, wherever it may be, as inevitably as the needle will follow the pole; and the more attractive the colour, the more inattentive does the eye become to surrounding attributes, however important they may be, so that it is really of much consequence that the colour afforded by ornamental bricks and tiles should be carefully and judiciously applied.

Fifthly. As to their employment in the construction of arches. Arches appear to offer peculiar facilities for the exhibition of the wildest vagaries. In the buildings to which especial reference has been made, they are coloured so as to look more like pyrotechnic displays than anything else. Blacks, reds, yellows and whites alternate, as in a catherine wheel, but their combination is far from being so satisfactory. Instead of preserving the arch line, they sever it into segments, and by destroying its continuity, deprive it of its beauty. By some strange spirit of perversity their arrangement is so distributed that the darkest colours are where the light should be, and *vice versâ*; the key stone being quite light, and its adjacent voussoirs quite dark. This transposition effectively divides the arch into two parts, falling away from each other, owing to the absence of a crowning member to unite them. As the construction of arches necessitates the employment of bricks of finer quality than those required for the walls, a great temptation is offered to make them injuriously conspicuous, by giving them prominent colour. An arch to be useful must have its voussoirs of a certain depth, and to give it the appearance of stability, they should have something definite to spring from. If their depth be proportionate to the width of the arch, the proportions of the opening will remain undisturbed; but if they are not so—and they certainly cannot be where the openings are small—they will create a heaviness and depression of the most objectionable kind. It very seldom happens that the breadth of a brick arch can be made to bear a just proportion to the width of the arch itself, and as the probabilities are so strongly against it, it were better to render an evil, which is almost inevitable, as little offensive as possible, than to expose it to censure by making it unnecessarily prominent. The simple intrados of any arch, whether it be a semi or pointed, is sufficient to assert its claims to admiration; and it is very questionable whether any enrichment, except that afforded by delicately cut and sculptured mouldings, can materially contribute to its beauty. Again, in order to secure some apparent springing line for an arch flush with the wall face, one of two courses must be adopted: either the colour of its voussoirs must be continued vertically throughout the length of its jambs, or it must be carried horizontally by a band fulfilling the duties of an impost mould. In ordinary buildings the latter is the simplest and most common, but it not unfrequently happens that instead of the band being flush with the voussoirs, it is made to project before them so that it assumes more of the character of a string-course intercepted and broken at the openings, than that of a member intimately associated with them. If a series of bands thus employed as springing lines occur at two or three irregular intervals, they may improve the appearance of a building by adding to its deficient length, and diminishing its excessive height. In the neighbourhood of large towns, where land is so valuable that it is necessary to economise every foot, and to build as high as possible, they may be introduced with considerable advantage, provided that they do not offend by prominent colour or pretentious elaboration.

Sixthly. If they are introduced into the interspaces of cornices, extraneous entablatures, or other similar groups of mouldings, their arrangement and design must be bold and well expressed. Minute and elaborate prettiness will not only be ineffective, but they will, by their own indistinctness, disturb and confuse any shadows that may fall upon them. In cornices of good projection and where the mouldings are not very delicate, they may be employed with great advantage, provided that their colours are selected with reference to their position; for instance, by executing the boundary lines of a metope or panel between the consoles of a cornice with darker bricks than the portion so enclosed, the panel will appear recessed, and the console thrown forward, because the shadow of the latter will receive increased depth and value from the colour of the bricks with which it corresponds. Again, in bed moulds underneath dentil courses, a simple alternation of light and dark colours may be made to produce great richness with very simple means, if the effects obtained by the natural colours be well considered, and increased by unobtrusive art. Generally speaking, if coloured bricks be employed alone and not thrust forward into positions where they are not required among details of intricate and delicate section, and if their colours are disposed so as to be suggestive of some uniform principle of design, their services will not fail to be recognised and gratefully acknowledged. It is because they are cheap, attractive, easily accessible and available for so many various purposes, that they become exposed to all the indignities which ignorance or indolence can inflict upon them.

Except ecclesiastical buildings, where their merits have indeed received the fullest recognition, there are none which are more confirmatory of the views expressed in the foregoing remarks than some of the large mills and manufactories that have been erected during the last few years in and around many of our principal towns. Built though they be of the plainest and most substantial materials, and as devoid of all expensive and elaborate ornament as is consistent with their practical character, they nevertheless present features which command the highest admiration. There is a really grand mill near Wigan, in Lancashire, which I never pass with indifference, where coloured bricks have served the purposes of its designer well. They define its main proportions; they maintain its leading lines; they give variety to its long flat walls; they confer importance upon its almost countless openings; and they dispose themselves so as to create bold, rich, and most effective details; in short, they do all that coloured bricks ought to do, and nothing more. This estimable work has not been produced without a careful and studied application of the true principles of design. With all its attractiveness, it is evident that its cost has not been overlooked. While every feature performs, and faithfully performs the duties assigned to it, there is no appearance of lavishness or unnecessary profusion. Brain has done more for it than money: the designer's head, and not his employer's exchequer, has honoured the heavy drafts which have been made on its account. It may be urged that the vast dimensions of the building, the unbroken character of its leading lines, the regularity of its openings and wall spaces, and the simplicity of its requirements in matters of detail and ornament, all help to save it from the mistakes and incongruities which deface the "villa residence" in its vicinity. This may be the case, for it cannot be denied that in some respects it possesses advantages superior to those of its humbler neighbour; but the fact cannot be doubted that, had the same ability and knowledge been brought to bear upon both works, their estimable qualities would not have been so widely different, nor would they have been regarded with such unequal feelings of respect.

We have now considered the application of coloured bricks to two classes of buildings—to small domestic buildings, and to large manufactories. They have been selected from many others because they represent two extremes; the first being the exponent of the worst, and the second of the best results producible by the introduction of positive colour for the purpose of architectural enrichment. It were useless, on an occasion like the present, to do more than to specify a few of the characteristics of each of these classes, and to direct attention to the means which have been employed to destroy all the attributes of beauty in one, and to confirm and multiply them in the other. To take into consideration all the other classes in which coloured bricks have lately been made to perform so prominent a part would be simply impossible; but before concluding I may be allowed to refer to one, not purely architectural, but of great and ever-increasing importance, and deserving of the best consideration of those to whom it must ever be most interesting. It need hardly be said that we refer to railway buildings, viaducts, bridges, and principal stations, which are of great size, of regular and expressive outline, and generally constructed of bold and simple materials. These characteristics present unusual facilities for obtaining effective decoration by the employment of the economical means which coloured bricks supply, and it is much to be regretted that these means have so seldom been employed. Much might be said of the indifference which so many of our leading engineers have shown in all matters relating to the æsthetical portion of their works; if they prove satisfactory in solidity and structure, their attractiveness, or rather its contrary, is totally disregarded. A large contractor once remarked that he preferred undertaking work under an engineer rather than under an architect, because the former afforded more profit and less troublesome detail. This craving for profit is not peculiar to contractors, and has more to do with the deforming process under which our great capital is at present suffering, than ignorance of the means by which it might be avoided, or at least mitigated. If engineers and architects worked together upon the designs, which are confided to the care of the former only—and certainly their gigantic proportions justify such a combination of effort—there would be fewer of those incongruous combinations and offences to good taste, which increase in number and importance day by day.

THE EXHIBITION OF PICTURES, SKETCHES, &c., BY THE LATE DAVID ROBERTS, R.A.

It is difficult to say whether the decease of David Roberts is a greater loss to the artistic than the architectural world. He had become, during a long and active life, closely identified with both, and was unquestionably one of the few men who knew how to combine in his productions true and consistent outlines with the skilful handling of the brush. Half a century of industry has, perhaps, never been applied in this field with more success, and the enormous number of sketches and pictures which that period of time represents, is a proof of the versatility of his talents, and of his intense devotedness to his art. He was a self-made man, naturally straightforward and honest in his bearing and actions; he preserved the character to the last, and it procured him invariable respect, while the geniality of his disposition rendered him a welcome addition to every circle. In his early years he had pursued a far less ambitious department of art—that of scene-painter, and to the results of this training may be traced that extraordinary power of dashing in grand "effects" upon often the most scanty groundwork, which was one of the peculiar characteristics of the man. No more conclusive evidence of this could be afforded than is displayed in the vast collection of his sketches and studies for pictures which are now on view at the Conduit-street Galleries. To state that the walls and several screens are entirely filled with these is saying but little; the interest and value of the series consists in its masterly completeness and variety; and it is a matter of congratulation for the profession, that such works as these (as were those of the late Professor Cockerell) are now accessible for inspection in our architectural gallery. A descriptive notice of the other collection just mentioned appeared at the time in our Journal for December, 1863, and we now propose to point out some of the prominent features of the present series.

There are in all 873 works, in oil, water-colours, pencil and etching, and the subjects have been gleaned from England, Scotland, Belgium, France, Italy, Germany, Spain and Morocco, Egypt, Syria, &c. In the west gallery will be found, among the oil sketches, the original studies for many of his most celebrated pictures, while some of these are executed with a care almost equal to his more professedly finished works. In this room we would especially note the view of Antwerp Cathedral (10), the stately form of which is superbly rendered, and with an atmospheric truthfulness not often attained. So, also, there is a fine study of another church at Antwerp, the altar in the Church of St. Jacques (30), also two other interior views of the same building (43, 44), which give a complete conception of this famous edifice. St. Peter's, at Rome, formed the subject of numerous pictures, which will be remembered on the walls of the Academy, and here we see several of the first studies. It was a bold attempt to grapple with so grand a scheme, but the artist was signally successful, and the pains he bestowed may be readily conceived by examining the elaborate preliminary sketches in (38, 38A). But, perhaps, more notable still is the rendering of the Colosseum, both internally and externally. The vastness, grandeur, and simplicity of this ruin are just suited to Mr. Roberts' style of handling, and he has treated it with consummate skill in several delineations. There are a few other oil pictures of note, which were taken on the Continent, and a portion of an interesting series, which had occupied him of late years, on our own River Thames, but which it is needless to particularise beyond instituting something of a comparison between the character of his work at the different periods of his life; these latter being mostly expressed by merely a few dashes of the brush, aiming at effect only, without the slightest pretension to outline or detail.

In the great gallery, however, will be found the chief attractions of this exhibition, consisting of "drawings and sketches," chiefly in water-colours, and including the vast harvest which he gathered during his travels in the East in 1838-9. The subjects obtained in this tour were afterwards lithographed by his friend Mr. Louis Haghe, and published in the well-known work entitled "Roberts' Sketches in the Holy Land, Syria, and Egypt," the publication of which commenced in 1842, and occupied seven years in its completion. The impression which these sketches made when they were exhibited on his return was surprising, but not more than was warranted by their intrinsic merits. The ground had been but little explored previously, and by no one better qualified to seize on its characteristic features, or reproduce them more faithfully and expressively.

Mr. Roberts' facile pencil was never better employed than in producing this series of views, and so rapidly did he work that the memoranda of dates at the foot of many of them show that he frequently made more than one finished drawing, of the largest size, and crowded with detail, in a day. Of this collection, those made in Egypt are, probably, on the whole, the most interesting; and were we called on to single out any special ones from among these, we should certainly fix on the "Thebes," especially the statues of Memnon (86), "Luxor" (159), showing the great entrance to the temple—a grand picture; the "Gate of Metawala," at Cairo" (247), curious for its banded and striped walls; the two fine sketches of the Great Hall at Karnac (275, 279), and the exquisitely drawn buried temple at Edfou (280). The solemn "Temple at Philæ" (327), called "Pharaoh's Bed," is a familiar scene, so are the "Sphinx" and the "Pyramids," so ably given in (344) and (349). The impressive grandeur of all these is striking in the highest degree, though the same remark will apply with more or less force to all the Egyptian scenes. Of others, interspersed among these, the following are deserving of notice:—two illustrations of the Holy Sepulchre at Jerusalem (98, 132), showing the Greek Chapel, and the Chapel of Calvary; Es Souan (99), the ancient Syene—a charming seaview; the Basilica of St. Constantine at Bethlehem (115); an interior view of the "Church of the Convent of St. Catherine, Sinai;" Nazareth (141)—a wonderful study of colour and drapery; Cairo (148), with its curious Moorish arch to the doorway of Sultan Hassan's mosque; the glorious "Smaller Temple at Baalbec" (164), and its elaborate doorway to a larger scale (244), of which a slighter sketch is given in (259); the four views of the "Temple of Jupiter," also at Baalbec; and the fancifully rich pulpit (170) at St. Lô, Normandy.

It was after the publication of his sketches in the East that he left England, in 1849, for Paris, Holland, and Belgium, and in the following year he made a second visit to the last of these countries. Some of the fruits of these journeys are also now before us, the most noteworthy, perhaps, being the hasty but telling interpretations of the ancient hotels-de-ville, Louvain and Ghent in particular; a still larger collection of views of west fronts and portals of cathedrals, such as those of Rouen and Abbeville; also similar portions of the Churches of St. Maclou and Notre Dame, Rouen, and of Notre Dame, Paris, &c. Besides these, the picturesque timber domestic structures of these provinces were not overlooked; and he treasured a valuable series, from Normandy in particular, viz., at St. Lô (531, 589), Dieppe (576), and Abbeville (584).

The tour in Spain and Morocco had already been accomplished in the years 1832-3; and it resulted in a series of lithographs, published in 1837. A copious selection from the originals will be found on these walls.

Mr. Roberts visited Italy in 1851, for the first time, returning by way of Vienna; and his "academy" pictures of St. Stephen's Church in that city, are among his most celebrated works. A free study for one of these will be recognised in (592). In 1853 he again visited Italy, in company with Louis and Charles Haghe, and his industry throughout appears to have been surprising. Rome, Milan, Pisa, Venice, Naples, Pæstum, Verona, and many more places, were the scene of his pleasurable labours, which embraced every variety of subject, while the fidelity of his pencil in accurately defining every salient feature is amply borne out by a comparison of these sketches with more professedly elaborate drawings of the same from other sources.

To his native Scotland he usually paid a visit annually, adding to his portfolio of sketches; and he once commenced a series of *etchings*, intended to illustrate the monastic antiquities of that country. These were never completed or published, but proofs will be found in the present collection. Among the water-colours may be especially singled out various charming views of Edinburgh, both as it was and as it is; the sketches from Melrose, Elgin, Stirling, and Glasgow—most of them familiar subjects, but here treated with peculiar skill. So, again, we have, in a very few touches, in (475), a very truthful rendering of the effigy monument to Alexander Stuart, son of Robert II.; and, in (480), an equally effective version of the well-known interior of Roslyn Chapel.

Of sketches made in England there are comparatively few, and the majority of these are from London itself. It is remarkable that the first scenes he painted for Drury Lane Theatre, in 1822, were "Old St. Paul's," and "St. Paul's as it is," and that the latter was the subject of the last picture he ever painted on. But, besides London, there are many gleanings from the suburbs, and from the banks of the Thames; upon which latter he was continually engaged during the summers of 1861-3. Throughout his life he kept copious journals, in which are included pen sketches of all his pictures as they left his studio. A volume of the journal, and also some of his pocket sketch-books, will be seen in glass cases in the exhibition room.

The decease of Mr. Roberts was quite sudden, from an attack of apoplexy, which occurred on the 25th of November in last year. His age was 68.

THE RE-CONSTRUCTION OF MALAHIDE VIADUCT.*

By William Anderson, C.E.

(With an Engraving).

A few hundred yards from Malahide station the Dublin and Drogheda Railway crosses an estuary or bay, partly on an embankment and partly by means of a viaduct 577 feet long. At the original construction of the line, this viaduct was built of timber, in eleven spans, 52 feet each. The general arrangement of this structure is illustrated, Plate V., Fig. 1. The obstruction to the free flow of the tide, presented by the embankment, caused a very powerful current to rush through the bridge, and it was very soon found that the soil into which the piles were driven was rapidly washing away, and the bridge settling down in consequence. To arrest this evil, large quantities of stone were from time to time shot into the stream, till a bank was formed, averaging 130 feet broad, by 30 feet high, extending in continuation of the embankment, right across the tide-way (shown in Fig. 2.) By this means, and also by constantly packing up

* From the Transactions of the Civil Engineers of Ireland.

the rails in some places to nearly three feet, the viaduct was made to do its duty till the year 1859, when, serious signs of decay becoming apparent, the directors ordered their engineer, Mr. Marcus Harty, to prepare plans for the re-construction of the bridge. As this was a work presenting some engineering difficulties, and involving a large outlay, designs were also obtained from some English engineers of note, but none of them having been adopted, it is unnecessary to notice them any further. In arranging the design for a new viaduct, three things had to be mainly considered; 1st—the maintenance of the traffic during the execution of the works; 2nd—the widest possible tideway; and 3rd—the most durable material. The first and second considerations, together with the relative cost of the superstructure and piers, decided the number and length of spans, for these had to be so arranged that the piers might be constructed and the new girders laid without endangering the old foundations, while the order in which the new structure should be erected was determined with reference to the least obstruction of water-way. It would appear, at first sight, that the easiest plan would have been to take down one-half of the old bridge first, build the new piers on the site of the old ones, and complete the superstructure of one line; by this means much complication in arranging the traffic, and all danger of obstructing the water-way would be avoided. But it was feared that the old piers could not be disturbed with safety; that the hold of the piles in the ground was so uncertain, that any disturbance of the stones might loosen the piles to a dangerous extent, and, consequently, any works performed on one-half the piers would seriously endanger the other. The new piers were, therefore, placed in the water-ways, as shown by drawing in Fig. 1; the first three spans of the bridge were completed—first for the down and then for the up road—all the old work taken down, and the new water-ways cleared and levelled; the increased facility for the flow of tide thus obtained would enable four more piers to be built, the down line over them completed, then the up line; the old work again removed, and, finally, the remaining piers and superstructure laid in.

As regards materials, Mr. Harty proposed two plans: 1st—stone piers supporting cast iron girders, 26 feet span, with brick arches turned between them, and the road laid in ballast; and 2nd—stone piers, supporting wrought-iron beams, 52 feet span, with the roadway laid on the top of them, on timber sheeting in the usual manner. The very much greater liability of wrought over cast iron to corrosion from the effect of sea-water, was very strikingly exhibited in the old bridge, where the bolts and straps securing the wood-work were deeply eaten away, even where the surface showed a good coat of paint, while the cast iron sockets and shoes, though unpainted, were almost free from rust. This fact induced Mr. Harty to recommend the first plan, but the strong prejudice which exists against the use of cast-iron in situations where failure might lead to most disastrous consequences, swayed the directors to adopt the wrought-iron superstructure.

The first thing done, was to prepare nine light travelling cranes. They were very ingeniously and cheaply extemporised, by converting pairs of old engine wheels into turn-tables, fixing them on the body of an ordinary ballast waggon, and arranging on them a wooden framework and jib, carrying an ordinary contractor's crab. At the same time stones for the piers were being delivered at the Dublin terminus, and as the season was advancing towards spring, and no time was to be lost, six or seven quarries were laid under contribution; 1703 tons of stone in all were worked up—calp for the rubble masonry, and limestone for copings. The dressing of the stones was all done at the Dublin terminus; the piers being actually built up dry, the stones marked, transported to the bridge, and the piers again built up dry, but turned bottom up, alongside the line, on the embankment close to the viaduct. The working drawings of the iron-work were also got out; tenders were invited from a few firms in Ireland and England, and the contract ultimately given to Messrs. Courtney, Stephens, and Company, the firm with which the author is connected. There was no contractor for any other part of the work; it was all executed under Mr. Harty's personal superintendence; a great portion, however, was done by piece-work as will presently appear.

As soon as the various preparations were sufficiently advanced, the works on the bridge commenced in March 1860, by carefully straightening and levelling the roads to the exact lines they were to occupy in the new structure. Switches were laid in at both ends of the bridge to turn the traffic at pleasure to either line; signals were erected near the point-levers for the guidance of the trains, the approach of which was notified, as soon as they came in sight, by the ringing of a bell fixed on the middle of the bridge. Over the site of each new pier a cross-road was laid, projecting sufficiently far over the water on each side to admit of a crane standing clear of passing trains. The rails of the main line were nicked out to allow the flanges of crane wheels to clear; and, as the sheeting over the new piers had to be removed, the main line rails, where they happened not to be over the wooden beams of the old bridge, were strengthened by bolting short pieces of rail under them. Seven workmen's huts were extemporised out of third class carriages; while the engineer took good care of himself in a snug office, built on the north abutment, in the castellated style, tastefully decorated with coal tar. A siding was laid on the north embankment for the pilot engine, which remained in attendance throughout the work. Two boats and a boatman were provided, the latter stationed so as to be in readiness to render assistance in case of accident to the men, and life buoys were placed on the bridge for the same purpose. In spite of every precaution, however, the author grieves to record that one of his men fell into the tideway, was swept away by the resistless current and drowned; his body was not recovered for a fortnight. The rush of water under the bridge was at times awful. Some idea of its force may be formed, when it is stated that a dam composed of about 4 tons of 80 lb. rails, bolted together to form a boom, with stones and sods among them, was washed away on the night of May 4th. The ends of some of the rails may even now be seen, so tightly jammed among the stones and rocks, as to resist every available means of recovering them.

Before describing the method of constructing the piers, it is necessary to mention that the bank of stones, thrown in to support the bridge, was assumed to be ample support for the new work, nothing more being required than to consolidate and level the base of the pier. A reference to Fig. 1 and Fig. 2, will show that the pitching thrown in to support the old bridge had been piled round the base of the piers, forming thus two sides of a dam; the tide fell away very rapidly from the east side of bridge, which, therefore, required no dam, and it remained only to arrest the shallow but rapid stream which was caused by the discharge of the pent-up waters of the estuary. This was done at first by a dam of sods, kept down by rails and stones, but after the accident already described, the following plan was adopted. On the west side of the tide-way to be dammed, a curved track was cleared at low water, the ends resting on the pitching round the old piers, and the convex side turned against the pressure of the bay; a wall of sods was then built up in the track, and securely pitched with stones on both faces, the form of the sides and top being such as to impede the flow of the water as little as possible, when once the tide rose too high for continuing the works. This dam was, after all, only a very imperfect protection, as the water found its way through the loose stones in every direction, so that all the foundations were laid under water. In preparing the site of the piers two plans were adopted. At first the loose stones were removed, to form a level bed at the proper depth, about 15 inches below the general surface, and the edges of the hole thus formed were built round with stones, set on edge without cement, the work being all under water; the space was then filled in with shivers mixed with iron-turnings to concrete them, the whole being rammed down, as long as any yielding could be perceived, by means of a 5 cwt. block of iron. To prevent the ram splashing into the water, a layer of stones was laid on the top of the real formation, and removed after the ramming was complete. Later on, however, this method was modified in favour of large flags, laid some 7 inches below the bottom of ashlar, and rammed down as before through stones temporarily filled in on them; the building of the edges with pitching was also discontinued until after the first courses had been set. As soon as a firm and level base was obtained, a framework of old rails (shown in Fig. 3), being the contour of the base of the pier, was laid down, and when adjusted at the proper level on a few blocks of stone, the intermediate spaces were carefully packed with flat stones all along under the rails, and the interior space filled in level with their upper faces, a grouting of cement being sometimes poured in if the state of the water permitted it.

On this foundation the first course of ashlar was laid, and the pier carried up very rapidly, the stones being taken down from their places in the pier on the bank, run on to the bridge in a hand lorry, and lowered very rapidly by two cranes, one working on the cross-road and one on the blocked-up main line. Lewises were at first tried for slinging the stones, but subsequently abandoned for common chain hooks, which answered equally well. Medina cement (Nine-elms) was used for the work set in water, or when the work would very quickly be covered by the tide, and Roman or Portland for the rest. The piers are remarkable for having no plumbing quoins of any kind; they were built from centre lines stretched from a vertical post erected a few feet beyond the cut-waters of each pier. Templates were made for each course, as the batter was in from every side, the correct position of each in the length of pier being given by a standard length from the guide poles. Stone pitching was carefully packed all round the new pier, to guard it as much as possible from the violence of the current. After the old bridge had been removed the water-ways were carefully levelled, the gain in tideway being about 35 per cent.

The first stone of the first pier was laid April 14th, 1860, that of the eleventh, on September 19th, 1860; about twelve days elapsing between the commencement of each pier. During this time, however, a great deal of the old bridge was removed, and some casualties occured, as for instance, the dam of No. 2 pier failed on May 4th, as already described, and on the 8th of the same month the increased rush of water, occasioned by obstructing the first three water-ways, caused a breach in the fifth, which took 70 tons of stones to repair; and on September 17th the dam of No. 11 pier gave way. There was also delay of about a month from the inability of the contractors to get the iron-work for the first three spans ready in time; so that on the whole it will be admitted that the work was done with very creditable rapidity, mainly due to Mr. Harty's admirable arrangement, great forethought, and unwearied personal exertions. It should also be remembered that all the works had to be arrested for the passage of every train, and that a great deal of the laborious work was done during the two hours or so of low water. The abutments were originally built of stone, and very little alteration in them was necessary. The cost of the rock ashlar, dressed at the terminus, ready for building into the piers, was 14½*d.* per cubic foot, the same stone delivered, dressed, from the quarry, 13½*d.* per foot cube; and it was found that 10·7 cubic feet of dressed stone was procured from a ton of rough; the real weight of the stone being 13½ cube feet to the ton. The cost of transporting stone, building piers dry, twice over, and finally setting the work in its place, could not be kept separately, as from the nature of the case it was performed in broken time. The watermen did their work by the piece, the following being the cost of founding each pier:—Removing dam from last pier; damming west end of old arch and maintaining the same; filing and discharging stones and sods for dam, from quarry; sinking old waterway for foundations of new piers; setting flags to near the proper level, and guide-post stones; covering flags with stone shivers and gravel mixed with iron turnings; ramming down flags with 5-cwt. ram; removing shivers and stones, and helping to set up guide posts; getting down rails, levelling and centring them accurately; flagging among them in shivers and iron-turnings to level of rails; attending to masons to the completion of first course of ashlar on rails; packing under outer edge of ashlar base; packing round pier and east apron; loading bottom to pitching and slope of apron; loading and discharging all stone required from quarry, £15. Bending rails to form of cutwaters, and securing them to form of foundation; drilling and rivetting to plates at ends; and 4 fish rails and 2 cross rails near centre, each £3. Cutting rails for a cross crane road over each new pier—crossing, square, the up and down main lines; cutting flange gaps in main lines, and 8 plates to go under them, including drilling, &c., £1 10*s.* When the rails of main line were unsupported, and made beams of, per rail, 2*s.* 6*d.* The two upper courses of the piers were of cut limestone, into which the cast-iron wall-plates for the beams to rest on were sunk. As the new piers had to be built in the water ways, it follows that, if the regular spaces were preserved, the end spaces would have to be either ½, or 1½ times the old ones; but, as so great a difference would have been inconvenient, the first and last piers were placed so as to divide a space and a half into two; the new viaduct consequently consists of 8 spans of 52 feet, and 4 spans, 40 ft. 2½ in.

The depth of the larger beams is 3 ft. 6½ in. between the intersection of the lattice bars, or nearly one-fourteenth of the clear span, the piers being 3 feet thick at top. The shorter beams are reduced in depth, in proportion to their length, so that in both the number of lattice bars is the same. Each span is composed of six beams connected together by horizontal and vertical cross-bracing; four beams being immediately under the rails of the two roads, and two beams under the handrails. Longitudinally, the beams are connected rigidly on every alternate pier, resting immovable upon it, while the remaining piers are provided with expansion rollers, (Figs. 5, 9, 10,) the upper flanges of the beams being merely held in position, laterally, by a joggle secured to one beam only. In order to avoid exposing a large surface to the action of the spray and sea air, the flanges of the beams are made as narrow and thick as possible, while the lattice bars in compression are made of thick bar iron instead of the more advantageous section of **T**, **L**, or channel iron. In addition to the amount of material necessary to meet the strain, ⅛-inch thickness all over is added to the roadway beams, to compensate for corrosion: the outer beams under handrails are, in other respects, of the same strength, in order to secure protection to carriages getting off the rails.

The load on one of the larger road beams is thus estimated:—

Pitch pine planking, 4 inch thick . . .	1 ton	10 cwt.
Gravel strewed over same . . .	2	0
Rails and sleepers	1	10
Diagonal cross bracing	1	0
Beam	6	0
Passing Load, ¼ ton per foot . . .	25	0
Total,	37	0

Thirty-seven tons, uniformly distributed, being rather more than ¾-ton to a foot run, and for this load the strength of the flanges is adjusted: while to meet the contingency of an engine running on a very narrow base, with unduly loaded driving wheels, the diagonal bracing is further strengthened to sustain a concentrated load of 5 tons travelling over the beam.

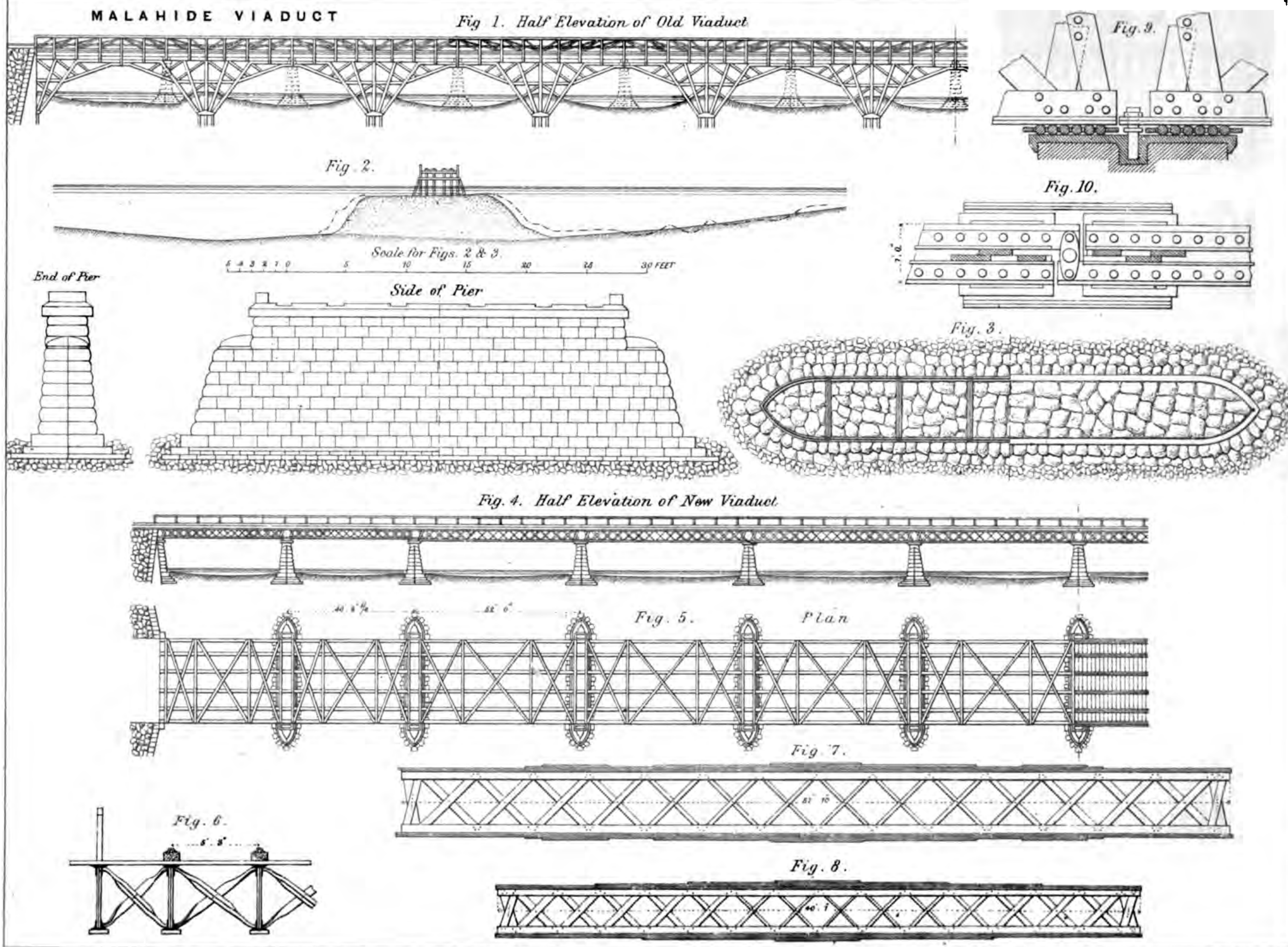
The shorter beams are similarly calculated to carry 28 tons each, with a concentrated load of 4 tons additional on the lattices. (Figs. 6, 7, 8.) The flanges of the beams are composed of pairs of unequal-sided angle-irons, with their deep sides between which the lattice bars are secured vertical; the necessary sectional areas being made up by piles of plates, decreasing in number from the centre towards the ends.

(*To be continued.*)

New Safety Light for Coal Mines.—MM. Dumas and Benoit have been making some experiments in the French collieries on the application of electricity as an illuminating power in "fiery" coal-mines. Voltaic electricity has been proposed on several occasions, as a means of giving light to the collier in dangerous places; but, under the ordinary conditions, it has not been found practicable to employ it. Dumas and Benoit propose to apply Rhumkorff's coil machine and Geissler's tubes; to use, indeed, those tubes, with their beautiful auroral light, as a miner's lamp, The tube, it is now generally known, is filled with some highly rarefied gas, and platinum wires are hermetically sealed into the ends. When the discharges from a Rhumkorff's coil apparatus are passed through this tube it becomes filled with a mild diffusive light, which lasts as long as the discharges pass through the rarefied medium. This light is unaccompanied by heat; it cannot, therefore, under any circumstances, explode the fire-damp of our coal-mines. This new "safety lamp" consists essentially of a cylindrical zinc vessel about 6 inches high and 4 inches in diameter, which encloses a porous vessel holding a cylinder of carbon. A solution of the bichromate of potash is placed *in* the porous cell, and dilute sulphuric acid *without* it. This battery is secured by a wooden cover, which is, by means of india-rubber packing, made to fit closely. Then there are a Rhumkorff's coil and condenser, and a Geissler's tube. This tube is arranged into a conical coil, so that a large surface of light is secured within a small space. The objection to this will be the cumbrous character of the machine and its adjuncts. Dumas and Benoit think they have answered this objection by the very ingenious arrangement which they have secured. It is stated that the weight of the glass case does not exceed two pounds, and that of the other parts of the apparatus not more than twelve pounds. The Institute of France has given the inventors a prize of 1000 francs for the ingenuity of their plan. Some trials have been made in the Newcastle collieries. The objection raised by the miners is, that the light is a "glimmer"—not a steady illumination.

Pl.

MALAHIDE VIADUCT



J.R. Jobbins

LECTURES ON ARCHITECTURE AT THE ROYAL ACADEMY.*

By Sidney Smirke.

Dismissing now all further reference to the subject of ornamental detail, I would somewhat enlarge the sphere of my observations, and suggest for your consideration the interest that may be given to buildings of small extent, or of unimportant character, by the application of the rules of good art to their design. Beauty and even dignity are surely capable of being impressed upon a building, although it may want prestige of nobility in its origin, and although it may lay no claim to the doubtful merit of mere bulkiness. I would be careful to guard myself from being supposed to advocate any attempt at giving an inordinate, or undue, importance to trifling works: what I would fain urge on you is, that they may be made to interest us, and even to excite our admiration, without any attempt being made to stilt them up to a level with great works. The hand of the *real* artist can never pass undetected.

It has been said of Virgil's rustic swains, such was the natural grace with which he seemed to invest them, that they appeared to perform the humblest and commonest tasks of rustic life with the dignity of gentlemen. So, perhaps, we may say with truth that buildings, even of the very least importance, may be raised high in our esteem by the artistic treatment of them.

It would be easy to multiply to any extent examples of this happy effect resulting from the judicious exercise of taste on minor works of architecture; and to illustrate the dogma that I would press upon your attention, that objects of architectural design do not derive their value so much from their intrinsic importance as from the quality of art bestowed upon them.

Take, for instance, the *bow window*, a peculiarly English feature which well deserves our regard and attention. Though so cheerful and pleasant a feature in dwelling-houses, it was, perhaps, in its origin, designed not *only* for light and prospect, but also as conducive to security in troublous times, as a looking-out place, giving a wider area for observation than would be afforded by an ordinary window. We see the idea of a bow window carried out, although somewhat timidly, in the Border castles of the North.

Subsequently, however, in Tudor times, when castles began to lose their frowning character, indicating a greater sense of security, and a desire to render home not only a place of refuge and defence, but also, to some extent, of domestic enjoyment, we then find them, as at Berkeley Castle, Kenilworth, and many other examples, assuming that particular character which afterwards became one of the principal attractions of an old English mansion. Indeed, we are justified, I think, in claiming this agreeable architectural feature as *peculiarly* English.

Bow-windows, no doubt, occur, in some form or other, in various parts of the Continent; scarcely even, perhaps, in Italy; not very commonly in France; but in Germany some types of the bow-window are, I admit, common enough. At Nuremberg, that great mine of picturesque architecture which every architectural student should visit and study, some particularly beautiful examples occur. Still there is a manifest local character that distinguishes all these German examples from the genuine old English manner of designing them. The Germans never appear to have so entirely departed from the ancient Gothic type, as we find to have been the case in English domestic buildings.

Their bow-windows are apt to look more like perforated towers than with us; and there seems to have been retained a special disposition to place them at the *angles* of their houses, as if covertly intended to command the sides of the building, as the bastion of a fortification commands the curtain. Our Tudor bow-windows, on the contrary, seem more designed for interior domestic enjoyment. As Bacon says of them, "These be pretty places for a conference," and it is certainly obvious that our ancestors, in building these bows, were far more bent on providing means for the pleasant occupation of a room than on producing any ornamental exterior effect. It is true, they are almost always extremely picturesque, and never fail to contribute to the beauty of the building of which they form a part; but this only tends to prove what on former occasions I have repeatedly urged, that in design, whatever is peculiarly fit and proper for its individual purpose rarely fails to be agreeable in its appearance.

Whilst dwelling on those subordinate parts of a building which the genius of artists has loved to endow with especial beauty, I must not forget to do justice to the chimney-shaft. Out of these trivial and uncleanly smoke-vents architects have taxed their ingenuity to produce really marvellous objects of high æsthetic value. Of *classical* interest they can scarcely be said to possess any, for it is very doubtful whether architects of classic times recognised the existence of such a feature. Vitruvius does not even name them. The remains of Herculaneum present not a single example of one; nor do the mosaics, frescoes, or bas-reliefs of antiquity show any indication of one, as far as I know. There is every reason to believe that the only means of escape for the smoke of their fires was through a hole in the roof, like the louvres of Mediæval times; so that the "smoke nuisance" we complain of at the present day may lay claim to high antiquity. The very name of the large hall in a Roman's house, *atrium*, is believed to be derived from this nuisance. "*Atrum enim erat ex fumo.*" The statues in these halls are described by Juvenal and others as "*fumosi*;" and Vitruvius advises that there shall be no carved work in the interior of winter rooms, as they so soon, as he says, get covered with soot. I apprehend that the roof timbers of our old baronial halls must have presented much of the same appearance; and as Horace complains of the "watery eyes" produced by the smoky halls, so our own mailed knights and their retainers could hardly have been better off. You will find that antiquaries are by no means satisfied as to the period of the introduction of this great domestic convenience, the chimney; but it was somewhat late in Mediæval times before chimneys became very common. Viollet-le-Duc gives us in his "Dictionnaire Raisonné" a good example of one of the thirteenth century, formerly existing in the Abbey of St. Lô, and in England we have examples of still earlier date; but as civilisation advanced, and men's domestic habits refined, the chimney became conspicuous. They lavished art upon the decoration of the hearths below; whilst the chimney above partook of the same feeling, and both gradually grew into favorite objects of design, until, in the sixteenth century, the exuberance of architecture,—especially, I think, in France,—led to the erection of those enormous and elaborate towers which we see provided for the discharge of smoke at Fontainebleau, the Tuileries, and very many other places.

The hypercritic may ask, why clothe these subordinate features with the dignity of art? Why bring out into so great importance and conspicuousness objects which have so mean a use? The artist, I apprehend, will rejoin—why *not*? Why should we *not* give to these chimneys any amount of beauty and expression that such objects, trivial though they may be, can be made susceptible of, provided we do so honestly, and keeping within the limit of good sense? To give to a chimney-shaft the air of an embattled turret, with loophole and crenellation, would be a falsity and an outrage on that good sense to which all things in art should be amenable; and indeed, to make them appear to be anything but what they are would be a fault of which I should be ashamed here to defend or extenuate. But that it should be considered unworthy of the dignity of art to descend to the adornment of even a chimney-shaft, by beauty of proportion, as well as of detail, merely because it is an object subservient to a very humble purpose, is what I feel bound to deny.

At all events, let not the architect think that he can afford to *slight* any portion of his inventions. "*De minimis haud curat Prætor*" may possibly be a sound maxim in law,—and even that I apprehend admits of a doubt,—but the arts of design are subject to a far milder, less severe rule; and, I repeat it, an architect cannot adopt such a rule of conduct without abandoning a part of his plainest duties, and at the same time abandoning a large and fruitful field for the exercise of such genius as he may be endowed with. I have now urged this principle upon you by referring to various minor details of architecture. It would be easy to greatly extend the number of similar illustrations, but perhaps we should profit more by enlarging the scope of our observations, and by showing how the same principle applies to the designing of whole buildings as well as of their details. I would wish you to consider that buildings of small dimensions, and appropriated to subordinate and even very insignificant purposes, may yet be made pleasing and interesting objects by a judicious application of the resources of art. But before endeavouring to enforce this opinion by special illustrations, let me assure you that I am by no means about to lead you into that vulgar error of which we see so many evidences constantly presented to our view, of that misapplication of art which con-

*See *ante* page 59.

sists of loading small buildings destined for humble purposes, with excessive or obtrusive decoration. On the contrary, that is a practice against which I would strongly protest. In like manner, I would warn you against another error common enough, and perhaps all the more dangerous on that account, of giving, or attempting to give, to those smaller buildings, a *character* that belongs to other more important works. To design a gate lodge so as to represent some classical temple, or to deck out a tavern, or a shop-front, as if it were a temple of Osiris on a small scale, these are vulgar habits which I beg of you to avoid, as repugnant to good sense, and derogatory to your art. No delicacy of finish, no exactness of representation, no excellence of execution, will compensate for so great a violation of propriety. Indeed, this disregard of the *appropriateness* of style—this ambitious assumption of dignity, incompatible with the size as well as with the character of the building, never fails to bring on the work, and on its author, the condemnation, and perhaps the ridicule of sound critics.

However, as I have already said, very trivial buildings are capable of beauty and expression, that beauty not being sought in excessive or inappropriate decoration, and that expression not being enforced by resort to theatrical or obtrusive artifices. The idea which it may be desirable to express should be delicately hinted at, rather than forced on the observer. Perhaps I may best illustrate the principle that I am endeavouring to present to you by hypothetical cases. Suppose, for instance, that a bailiff's or a gamekeeper's lodge has to be built, in one of those ornamental and picturesque parks with which English scenery is so often graced. One ambitious architect will overlay his ornaments upon it from plinth to roof; his ridges will be bristled with a luxuriant cresting; his walls will be speckled over with bricks of all manner of colours; he will give it perhaps two or three very pert-looking gables; his bow-windows and porch will present a complete storehouse of crockets and corbels; tall chimney-shafts will of course not be wanting elaborated after the types of Hatfield or Knowle; in short, there will be a whole world of art within the compass of this nutshell. Another architect, whilst he gives to his work that careful and even polished aspect that is demanded by the genius of the place, will yet keep it subordinate and unobtrusive. He will not force it upon your notice, but rather would let you perceive it amidst a becoming veil of foliage: like the modest rural belle of Virgil, she is retiring, but not unwilling to be admired:—

"Fugit ad salices, at se cupit ante videri."

His work will present nothing to your view either ambitious or sordid. Ornament will not be wanting, but it will be sparingly used and suitable in character. There will be elegance, but a total absence of ostentatious ornamentation. In both these supposed cases there may be beauties, but in the one case there is an incongruous display of them; in the other case, its beauties are but modestly disclosed, and have to be sought for in order to be duly appreciated. Which, I ask you, of these two men's works would best deserve the name of *fine art*?

It is, I fear, a deplorable fact that the present day is distinguished by far too great a prevalence of the evil taste to which I advert. Æsthetic cultivation has not kept pace with the accumulation of the means of indulgence in the luxuries of taste. I believe that many an architect finds himself, contrary to his better judgment, constrained to work *down* to the level of his patrons, and erects unsightly examples of misplaced finery to meet the exigencies of such patrons, whilst he is conscious of higher and worthier aspirations. I am treading, however, on hazardous grounds, and must proceed no further. I will, therefore, at once dismiss the subject, merely remarking that, however improvable may be the fine-art education of my profession, no improvement would be so productive of good, and none so needed, as an improvement in the knowledge and appreciation of the art *outside* the profession. But for the enlightened perception of the beautiful in a Pericles—and, indeed, in the Greek culture generally—Greece, perhaps, would never have had a Phidias. It was the ardent love of art, and the earnest study of it, in Lorenzo di Medici, to which may be justly attributed that memorable school which gave us Michelangelo and all the other glories of his age.

I have observed on the capacity of even very small buildings for beauty and expression, without that resort to excessive decorative detail which is supposed by some to be so essential. Examples in endless variety might be adduced in verification of this opinion. The cottages that remain to us of the sixteenth and seventeenth centuries have often a most pleasing character, contrasting painfully with the ordinary cottage of the present day. Notwithstanding the simplicity of design and the apparent absence of all effort at "effect," there is yet a play and variety of form, and breadth of light and shadow, which will produce, by chance, as it were, a most picturesque object; and this desirable result, let me add, will be often found to be brought about without a single *merely* ornamental adjunct. When these humble yet pleasing structures happen to occur beside a cottage of the ordinary type of the present day, it is impossible not to admit that in matters of taste, at all events, the world makes very slow progress, if it be not retrograde. The utilitarian spirit seems to have completely extinguished the feeling that prompted the cottage builders of former times; so extinguished, indeed, that the rash man that would venture to insinuate a doubt whether we might not derive valuable lessons from these very unpretending works of our simple forefathers would probably meet with far more derision than sympathy.

Do not suppose that I am not alive to the very important improvements that have been made of late years, in the domestic arrangement of cottages. It would be a gross injustice to many able and benevolent men who have laboured in the good cause of bettering the material condition of the humbler classes, were I to deny that great success has attended those efforts; there is not a doubt that the interior economy of cottages has been wonderfully improved, and that the health of their occupants, both moral and physical, has been greatly promoted by those improvements; nor do I hesitate to admit that these are considerations which have a far higher claim on our attention than the merely picturesque consideration which I have been noticing, and to which it is perhaps my duty *here* to confine myself. My object in touching at all upon the utilitarian view of the subject is to suggest to you, as artists, not that the first place is to be given to artistic excellence in these humble productions, but that art should not be altogether overlooked in them; and to urge upon you the duty which, as it seems to me, devolves on all who love their art, to study seriously and carefully how to reconcile and adopt the high qualities of beauty and expression to the severer virtues of convenience and healthiness.

At the risk of being charged with extending my remarks on this cottage architecture to an unreasonable length, I am strongly tempted to point out the fertile source of profitable study to be derived from the critical observations of the villas and other rural buildings that so often meet the eye of the observant artist who wanders over the campagna of that land of art, Italy. They are for the most part the works of former and better times, and illustrate forcibly the picturesque tendencies of the Italian mind. Every group of these unostentatious structures that we meet with is apt to arrange itself agreeably, and to become in itself a picture, attractive to the painter's eye and inviting his pencil. *They* are not tricked up exhibitions of artistic coxcombry; not theatrical displays, "smelling of the lamp," and betraying the vanity and vulgarity of their authors; but their charm lies in the unaffected grouping together of their very simple forms, pleasing us by the *accidental* beauty of the result. It may be difficult to explain the cause of the pleasure which these rustic buildings produce on the mind of the wanderer who has leisure and inclination to seek benefit from a contemplation of them. The pleasure derived from this exercise of the eye is to be felt but not described, and will perhaps best be realised by those who will take the trouble to compare these examples with buildings of like nature usually erected by ourselves at the present day, and in our own truly utilitarian country, from the contemplation of which we usually derive anything but satisfaction.

I must not detain you longer with these reflections. I might readily draw ample illustration from the works of the great painters of the Renaissance and later periods. I can assure you that even the *architectural* student who, in search of the picturesque in his own department of art, will examine the works of the great masters of the sixteenth and seventeenth centuries, will not fail to find the delicate perception of beauty which so greatly distinguished the Italian mind, eminently manifesting itself in the backgrounds and subordinate portions of the refined compositions of that golden period of art.

Now, when endeavouring to enlist your interest, on behalf of these minor objects of picturesque architecture, it may seem inexcusable that I should pass by without recognition, the almost proverbially attractive form and features of the Swiss châlets;

MOFFAT'S METHOD OF BUILDING UNDER WATER.

Fig. 1.

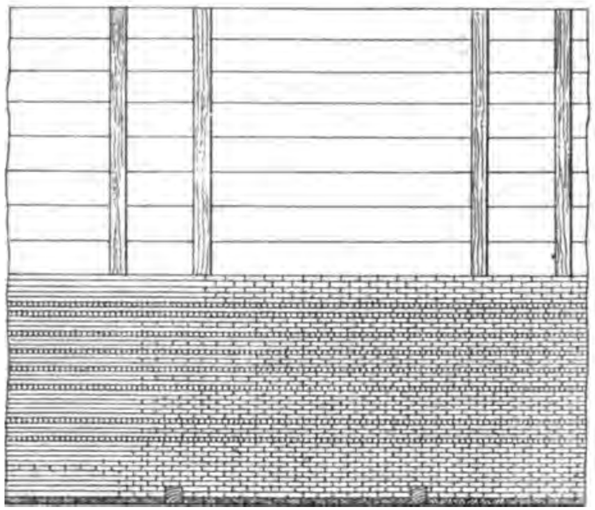


Fig. 2.

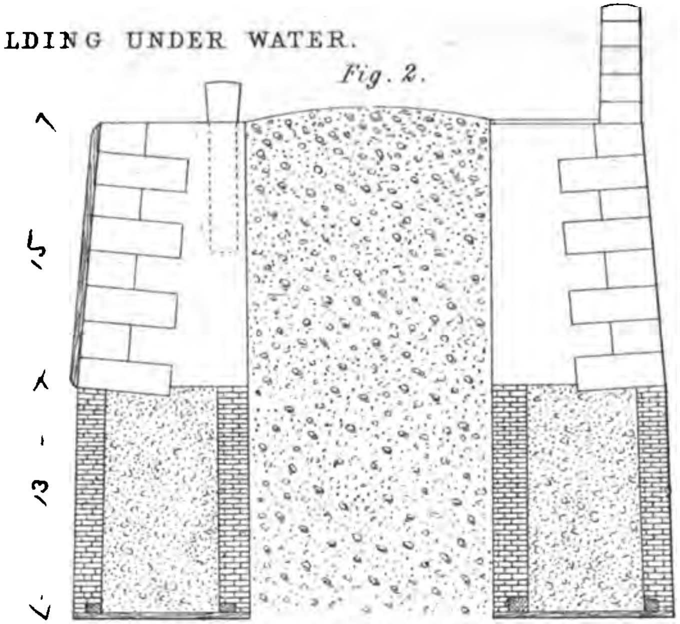


Fig. 4.

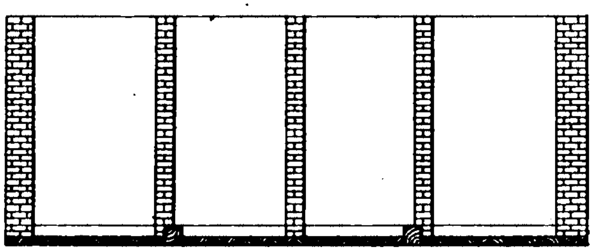


Fig. 3.

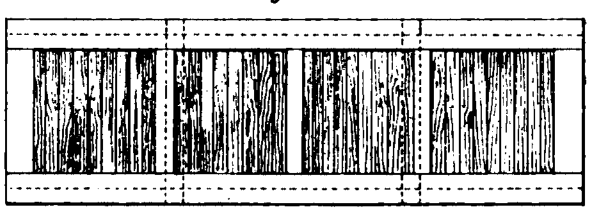
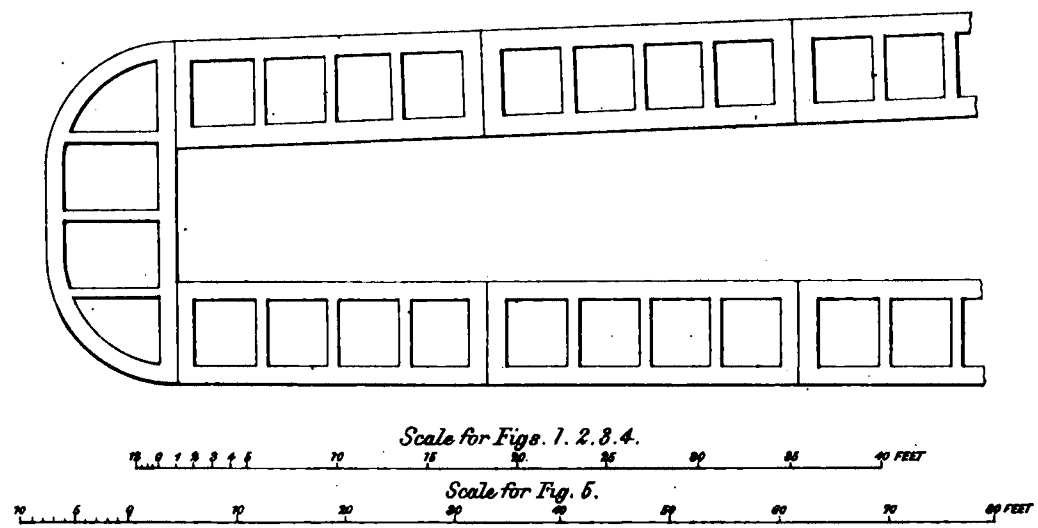


Fig. 5.



Scale for Figs. 1. 2. 3. 4.

Scale for Fig. 5.

J.R.Jobbins.

but they are objects so familiar to all, that we need not be detained by any special reference to them, except to point to them as a most obvious illustration of what I have been urging on you, namely, that in these smaller works of art, those will assuredly please the critical eye the most, which seek to give pleasure, not by multitudinous enrichments, but by an agreeable outline and chiaroscuro. The singular charm of those plain wooden tenements consists in their breadth and simplicity, in the unaffected rustic beauty which particularly characterises the Swiss châlet.

It is time to close these desultory remarks on small matters. Let me sum up in few words the perhaps not sufficiently marked or steady aim of all the observations with which I have been soliciting your attention this evening. I would not have you despise small objects of design. Never regard it as beneath you, nor beneath the real dignity of your art, to pay even minute attention to every object, however unobtrusive; for there is in designing nothing to which true art may not be applied with advantage. It is the slovenly neglect of these details which contributes, more than almost anything else, to make a design crude and sometimes even vulgar.

Some may be disposed to regard such inattention as a noble indifference to trivial matters, and as an evidence of true genius; but must we not rather look on this defect as a proof of the very narrow and finite range of human capacity?

Look, as I have often repeated in former lectures, to what Nature does, and no true disciple of art will ever think that he can too carefully pursue that study. In the works of nature we shall find, in the veriest trifle of organised life,—the tiny moth's wing, the fly's foot, even the dead leaf that is drifted as an utterly worthless thing before the wind,—that there is no less careful adherence to Nature's laws, no less thoughtful adaptation of means to the end, than in the most stupendous works of the creation; and yet we shall find that over all these minute though not less noticeable manifestations of Divine power and wisdom, there has been extended an all-pervading spirit of grace and beauty, a manifestation which should prompt the artist to follow humbly yet zealously the example thus set, and never to relax his best endeavours to endue his works, whatever they may be, with such touches of those heaven-born qualities as may be within the reach of his ability.

METHOD OF BUILDING UNDER WATER.*

By John Moffat, C.E.

(*With an Engraving.*)

Quay walls are the principal objects of subaqueous construction; and these have hitherto been made of wooden or iron framing, or of stone or brick masonry. In the former case they depend for their stability chiefly on the strength given by cohesion, and in the latter on that afforded by their weight. The security and durability of masonry, as compared with any description of framing, in every kind of harbour construction, are so great, that it would be invariably adopted, were it not for the consideration of time and expense. A pier can always be made of wood or iron much quicker and cheaper than of stone; and on this account they are frequently resorted to in cases where the time or the money at the disposal of the engineer render the superior structure unattainable.

About ten years ago I had an extension of the outer quay and breakwater at Ardrossan Harbour to execute, which had to be completed in one summer, and for a limited sum. All the works at that harbour have hitherto been executed in stone, except a small pier of timber, which, though cheap at first, turned out in the long run to be the dearest work we had, on account of its being destroyed by the *Teredo navalis* in about ten years. We had also found that cast-iron is corroded so rapidly, as to render an iron structure nearly as objectionable as a wooden one. And I was thus induced to turn my attention, to devising a plan for executing the building in masonry, within the limits assigned to me. And I succeeded in doing so, by the plan which I shall now proceed to describe.

In a stone pier, the portion which consumes most time and money, is that under low water. Hitherto this portion has been built in separate masses in wooden caissons, and floated to its position when completed, the sides of the caisson being disengaged when the mass of masonry had been set. Or it has been formed entirely of large squared ashlar, dropped into its place by means of water lewis, or set by means of the diving bell. At Ardrossan the masonry under water has been built entirely of ashlar, set partly in the first way, and partly in the second. Where set by the water lewis, the stones are laid so that the beds are not horizontal, but at an angle of 45°. After the first row of stones has been laid, and which must be done with very great care, the remainder are lowered so as to catch the upper edge of the inclined bed, and are slipped along it until they reach their position, when the lewis is disengaged in the usual way. Where set by the diving bell, the courses are horizontal, and form a solid mass of ashlar of the ordinary construction.

I found by calculation that with the plant at my command, I could not complete the extension, by either of these methods, in less than two seasons, and that the cost would exceed the sum at my disposal. It then occurred to me, that I could attain my end by forming the masonry under low water of large hollow masses of brickwork, constructed in the graving dock, and floated to their position in the quay, after reaching which they could be filled with concrete. And on trial I found that this plan could be easily carried out, and furnished a method of submarine masonry much cheaper and quicker than any I had yet tried.

The average depth at low water was nearly 20 feet; and I levelled out the foundation, and laid three courses of ashlar with the diving bell in the usual way, so that the upper bed was about 15 feet from low water. The hollow brick masses were made 15 feet long, 15 feet deep, and 11 feet thick. The bottoms were of cast iron plates ¾ inch thick, strengthened with projecting feathers along the edges. The walls were 20 inches thick, formed of large bricks 20 inches long, 10 inches broad, and 5 inches thick, set in Roman cement, and strengthened by horizontal strips of hoop iron laid along the courses. When finished they were nearly watertight, and their specific gravity was a little less than sea water. They were floated to their positions by being attached to one of the harbour punts, set at low water, and then filled with concrete. The ends were formed with alternate salient and re-entering angles, so as to lock into each other. The wall above low water was built of ashlar and rubble in the usual way; and the work was finished in a satisfactory and substantial manner in the summer of 1855. The length of the pier was fully 300 feet, the average breadth 70 feet, and the cost was under £10,000. The average cost of the brick masonry under low water was 7*d.* per cubic foot, or about one half the cost of solid ashlar.

The work has now stood for nine years exposed to a rough sea and a heavy traffic, and is as perfect as when completed. Four years ago, I had occasion to cut down the masonry to low water, in order to erect a 20-ton steam crane, which I constructed on the top of one of the brick masses as a foundation; and I found it then to be in the same condition as when set.

I had recently occasion to extend another of the quay walls, in water about 10 feet deep at low water; and this extension I resolved to construct in a similar way to the previous one, but in a cheaper manner. The bottoms were made of wood instead of iron, and the bricks were of two sizes, at the ordinary price, instead of the large size previously used, which cost nearly twice as much. I originally made the brick masses only 15 feet long, from a fear that larger sizes would be unmanageable. But having found them to be very easily handled, I resolved to make them on this occasion double the length, or about 30 feet long.

This extension was also successfully constructed in a very short time; and the drawings on the wall are intended to show the construction in detail. From the ground plan it will be seen that the extension is about 110 feet long, 35 feet broad, and the walls 27 feet deep. The bottoms of the brick masses, which varied in length from 29 to 33 feet, were formed of a light wooden framing, formed of two beams of yellow pine 9 inches square, to which was spiked a platform of 3 inch white pine battens. These were caulked so as to be watertight, and set on four logs on the bottom of the graving dock, as a foundation on which the brick caissons were to be built. The outer walls were formed of common bricks of two sizes—the one 9½ inches long, 4¼ inches broad, and 3½ inches thick; and the other 13 inches long, 6½ inches broad, and 3½ inches thick. These were laid in alternate courses—the small bricks in one course, and the large ones in another header and stretcher alternately, so as to give proper bond. The outer walls were thus 20 inches thick all round, and the front and back walls were connected by three

*Read at the Institution of Engineers, in Scotland.

cross walls one brick thick. The whole was set in Roman cement, and strengthened with hoop iron laid along the bed of the courses. The weight was adjusted, so that when finished they floated, with the top about one foot above the surface of the water,

The size was determined by the length of the logs from which the longitudinal timbers of the bottoms were cut. For these I selected logs varying from 29 to 33 feet long, and nearly 18 inches square, which were cut into four timbers, the full length of the log, so as to avoid any waste. The average size of the caissons was 32 feet long, 13 feet deep, and 10 feet thick. When the brickwork was finished, a small beam of timber was laid along the top, and connected with the bottom by means of two long bolts of wrought iron 2 inches in diameter. The water was then let into the graving dock, the brick masses or caissons were floated, and attached to the diving-bell barge, or to a crane punt, and towed to the place where they were to be set. They could be raised about 4 inches above the line of flotation by means of the crane on the punt, and were suspended at this level above the bottom, by means of the long bolts above described, until they were brought to their exact position in the work, when they were at once lowered on to the bottom, and filled with concrete. When they were set in their places, the top beam and bolts by which they were suspended were removed and used again. The concrete used to fill them was formed with a mixture of good hydraulic mortar and cement, and large gravel, in the proportion of 1 of the mortar to 2 of gravel, which I found to set in a short time into a very hard compact mass. All the brick caissons were of an oblong form, with square ends, except the closing one across the end of the quay, which was formed with rounded corners to a radius of 13 feet. I found that forming the ends with salient and re-entering angles caused a good deal of trouble both in building and setting, and was of very little use.

These operations were all carried on without the slightest difficulty. As a proof of which, I may mention that on one occasion I built four of the caissons in the graving dock at once, and floated them into their places in two tides, thus completing 126 feet of wall in twenty-four hours. When the brickwork was finished the masonry was begun on the top, and completed with a facing of ashlar and a backing of rubble in the usual way; and the space between the walls was filled in with stones.

The cost of the work was £1881, or £51 per running yard, being less than the cost of open timber piling, which would have been greatly inferior both in efficiency and durability. The cost of the portion under low water was 4*d.* per cubic foot, concrete included.

I may mention that I am at present constructing another wall in a similar way, and that I have made some of the brick caissons even larger than I have stated. But from what I have seen, I think that about 40 feet long is the largest size which admits of their being easily handled.

Of course the possession of a graving dock offers great facilities for the construction of these floating masses of brickwork. But there is nothing to prevent them from being built on the beach in sheltered places by tide-work, and floated off at high water when finished; or they may be constructed on the ground above the level of high water, and launched on slip-ways like a ship.

References to Plate VI.

Fig. 1. Elevation of pier.	Fig. 4. Longitudinal section.
Fig. 2. Cross-section of pier.	Fig. 5. Ground plan of pier.
Fig. 3. Ground plan of caisson.	

Dr. Macquorn Rankine said that he had seen the pier Mr. Moffat referred to, and also some of the caissons while in progress, and could testify that the mode of construction was most efficient.

Mr. Moffat said that the bottom was prepared with the diving-bell in the usual way. The first pier would barely have been finished in two summers by the ordinary mode of construction; but by using the 15 feet caissons it was done in one summer. The other one only took three months; whereas, with the use of the diving bell there would have been more than twice that time spent on it. He had built a pier in Fife, of the usual construction, for the late Mr. Baird of Elie, which was about 50 feet longer and not so deep as that at Ardrossan, and it cost between £5000 and £6000.

POMPEII.*

By R. Phené Spiers.

The subject of my paper is one which has not occupied the attention of the Association during my recollection; and I esteem myself especially fortunate in having the opportunity of introducing it, because I remember I looked forward to no portion of my route in Italy with greater interest than that which should include Pompeii and Herculaneum. And I am inclined to believe that the same feeling influences us all; and that, not only with a view to any practical hints in architecture or decoration which one might derive from it, as from the simple fact of being able to visit a city hidden from the sight of man for nearly seventeen centuries, and exhumed—as it were, restored almost to its orignal state, in all its pristine hue of form and colour. It seemed almost a dream or fairy-tale to imagine that we could wander through the same streets, look upon the same temples and monuments, enter the same doorways, and tread on the pavement of the same houses, as those who had lived 1800 years ago; and that all their features should be in the same condition as they were then. Generally the discovery of a wall, a gateway, tower, or temple, is looked upon with thrilling interest, and many are the learned dissertations as to their origin or original use. Here, in England, the finding of some ruin (now devastated by time and age, though still more by the destructive hand of man) constitutes one of the greatest pleasures that can be afforded us and should it date back five or six centuries, it is looked upon with the greatest respect, when we remember the length of time that has elapsed since the stones composing it were quarried, carved, and placed in their respective positions; and be it uncouth in the extreme, its age renders it sacred in our eyes, and we regard it with veneration, if not with admiration. What, then, shall we say when we are able to look at buildings—nay, a whole city—bearing no traces of modern restoration and beautifying, not the uncouth works of a barbaric age, but of a people far more elevated in the artistic scale than we are at the present day,—with a greater instinctive knowledge of form and colour, and with a greater power of displaying it in the different materials in which they worked?

Being the first time that this subject has been brought before the Association, I shall do right, I think, to give you a general description of the city and the chief characteristics of its architecture, decoration, and paintings, reserving special accounts of newly-excavated portions for some future occasion, when, after visiting the ruins a second time, I shall be better able to do so.

The ancient town of Pompeii was situate on the volcanic rocks of the Campania; its south and west walls washed by the sea; its east wall bounded by the river Sarno, which was then navigable for a short distance above its mouth. Though Seneca mentions it as a celebrated city, little is known about its early history. Its origin is generally ascribed to the Oscans, and its name is supposed to have been derived from the Greek word πομπεια, signifying "storehouses."

From its great richness, the country seems to have had the peculiar property of enervating those who settled there, rendering them an easy prey to invaders, who, enervated in their turn, gave place to some sterner enemy. Hence it was possessed successively by the Oscans, the Ausones (both these of Pelasgic extraction), Cumæans (or Etruscans), Samnites, and Campanians; these latter, in a second attack by the Samnites, threw themselves under the protection of Rome, about 360 B.C., and then sank down into one of the dependencies of that empire. About 91 B.C. they revolted, and then a colony was sent down from Rome to cultivate their territory and keep them in complete obedience.

In A.D. 63 a violent earthquake shook the city to its foundation, causing it to be almost abandoned for some months, at the end of which time the inhabitants gradually reappeared, and set to work to repair the damages done and rebuild the shattered edifices.

In A.D. 79 the great eruption occurred which covered Pompeii with showers of ashes and scoriæ, hiding it from sight, and thus preserving the greater portion of it more or less complete for our study and admiration. Herculaneum, situate at the foot of the mountain, was covered also with ashes and scoriæ; but the vast volumes of steam sent up by the volcano caused the deposit of these ashes in a liquid state, which solidifying became as hard

* Read before the Architectural Association.

and compact as lava; so that the excavations of this latter town are more difficult to make, especially as subsequent eruptions have gradually poured their lava over the town, which is now found at a depth of 75 feet below the present surface of the ground. These subsequent eruptions have been almost the cause of Pompeii's remaining more or less intact; for the inhabitants returned again after the burial of their city to search for its treasures; and would probably have settled there up to this present day (as at Portici and Resina, built over Herculaneum, after each successive eruption). As many as eight successive layers, some of lava, have been counted over Pompeii, and it is only the lower one, which first buried the town, that has been disturbed. This accounts for the fact that so few articles of intrinsic value, such as jewels and money, have been preserved. Pompeii remained buried for nearly seventeen centuries, and it is singular that Domenico Fontano, a celebrated architect, who in 1592 was employed to bring the water of the Sarno across the city to the town of Torre dell' Anunziata, and who in the course of the work must often have encountered the foundations of ancient buildings, should not have had his curiosity awakened as to their origin; in fact, the city was entirely lost till 1748, when a countryman sinking a well discovered a painted chamber, with statues and other objects of antiquity. This brought the attention to it of the king, Charles III., and in 1755 the works of excavation commenced, which have continued up to the present time, more or less slowly; so that after a lapse of 120 years, probably not more than one-third of the city has been excavated.

Before the laying down of the railway, the visitor generally entered Pompeii by the street of tombs; and a more fitting entry to the desolate and empty city could not be well afforded. The street rises as it approaches the walls, and is lined on each side by a series of tombs, some of great magnificence, it being a Roman custom to bury the dead not in cemeteries or spaces set apart for that purpose, but along the principal and most frequented roads leading from the town; thus the Via Appia, at Rome, is fringed on either side with tombs, for upwards of 13 miles away from the city. The Romans, as you are aware, burned their dead, and then, collecting the ashes, placed them in small jars or urns (the origin of those frightful features in our modern churches and cemeteries): these were deposited in vaults, in the walls of which were small niches resembling pigeon-holes, for which these vaults have acquired the name of columbaria. The tombs consist for the most part of a small altar, either square, oblong, or circular in plan, raised on two or three steps, the whole carried by a pedestal or podium (in the interior of which was the vaulted chamber), and a small inclosure with low wall around.

The upper portion, or altar, of these tombs, was generally in white marble, with bas-reliefs and inscriptions on them recording the virtues and exploits of those buried beneath. The podium was in masonry, ornamented with stucco decorations, and sometimes painted. Near the city gate are some tombs of larger size, one of the priestess Mammia, built in stuccoed masonry adorned with columns, the walls of the interior covered with arabesque work: two large exedra or semicircular seats in stone, and a hemicycle or large niche very richly decorated, are still in very good preservation. In this street of tombs are also one or two villas or suburban residences; of one of which, the "Villa of Diomede," I shall have a word to say farther on.

The walls surrounding the town have been traced throughout their whole extent, so that the size of the city is known. They are not more than two miles in length; and the space enclosed, about 160 acres, is of the form of an egg, at the apex or smaller end of which is the amphitheatre. The walls were of great solidity and width. They had a double parapet and terrace, the latter about 14 feet wide, sufficient to admit of two chariots passing abreast. It was carried by two walls, the outer one with a slight batter, 25 feet in height, the inner wall about 40 feet, and occasional flights of steps on the city side to admit of easy access on to the terraces. The walls are built of large blocks of volcanic tufa and travertine in horizontal courses with inclined joints; and on some of the stones are found Oscan inscriptions, so that these date probably from the foundation of the city. Square towers are placed at intervals along the walls. The battlements seem to be of later date, being built in that kind of work called *opus incertum*, the rubble work of the ancients.

There are eight entrance gates to the city, five of which are mere ruins; of the three others, the gate of Herculaneum, through which we enter the street of tombs, is the most perfect. It is in Roman architecture, built in alternate courses of brick and lava, and consists of a central archway, 14 ft. 6 in. wide, and two side ones for foot passengers, 4 ft. 6 in. wide each, these latter vaulted throughout their whole length. The central passage, of which the arch is gone, seems to have had an open space in the centre, so that the enemy who had already forced the portcullis might be attacked from above whilst endeavouring to force the second door which swung on pivots. The height of the arch is calculated at 20 feet.

Outside the gate was a niched tomb, long taken for a sentry-box, from the fact that the skeleton of a soldier, in the usual accoutrement and arms, grasping a lance, was found in it—instanced as a proof of the excellent and praiseworthy discipline of the Roman soldier, who remained faithful to his duty to the last.

The streets are for the most part straight, and run at right angles to one another. They are not wide, many of them not admitting of the passage of more than one chariot at a time; and probably these were not much used, taking into account the small extent of the city (only three-quarters of a mile in length, and half-a-mile in width), though the deeply worn ruts in the stones would seem to indicate the contrary.

The roadway is composed of huge polygonal masses of lava, from 9 inches to 18 inches in diameter, and 9 inches in depth, closely fitted together. The stones were worked in a wedge shape, so that they spanned the roadway like a vault, each stone resembling the voussoir of an arch. All the streets have pavements for foot-passengers, even those where chariots could not pass, consisting of curb-stones of lava, with the pavement composed of bits of marble and stone, set in cement, the whole rubbed flat. In places were the curb-stones have broken away, they have been cramped together with iron. These foot-pavements are elevated sometimes more than a foot above the roadway. It is supposed that the later, in times of rain (which falls very heavily in those countries), becomes a kind of sewer, as all the streets are slightly inclined one way or the other; and this supposition seems well founded, because there exist everywhere huge stepping-stones from pavement to pavement, the wheels of the carriages and the horses (always two) passing on either side of the stone. The way in which the solid refuse of the city was carried away is still a mystery, scarcely any trace of sewers having been found. Mazois gives us a drawing of one, the position of which he does not state; but it seems only to have served to carry the waters from the street under the walls to outside the town. It is just possible that the streets may have been the only sewers, as they are still in some towns in the East.

Though traces of aqueducts are found in the country around, it is not known with any great certainty from whence Pompeii was so plentifully supplied with water, there being no wells.* A very large numberof leaden and earthenware pipes have been found, the former of which supplied the numerous fountains which were placed in all the principal streets. They consisted of a cistern, formed of blocks of lava, cramped together with iron, the water falling into them through a pipe fixed in one of the back stones of the cistern, which rise higher than the rest.

Public Buildings.

The public edifices and monuments of Pompeii give more direct information as to its history than aught else. The more ancient are essentially Greek, both in plan of building and style; the later edifices show the influence of Roman customs and habits, though always preserving a certain Greek feeling.

In a description of a Roman city, the forum is the first place to which we should direct our attention, as the centre of business, the resort for pleasure, and the scene of all political and legal contention.

The Forum is the largest and most imposing spot in Pompeii, measuring 500 feet in length, and 150 feet in width. It was surrounded on three sides by a portico of Doric columns, set wider apart than usual, so that stones could not be depended upon to span the distance between them; and accordingly wooden beams were used, on which rested the stone entablature, in the back of which holes were cut to receive the ends of joists of a gallery, which extended over the portico round the forum. Several pedestals of masonry, deprived of their statues and marble coatings, still exist, and some bear still the names of the distinguished inhabitants in whose honour they were erected.

* One deep well has been recently discovered, with good potable water in it.

At the north end of the Forum is situate the Temple of Jupiter, on an elevated podium or basement, reached by steps flanked on either side by pedestals for statues. The temple has a portico of six columns in front, and three on the side. The columns are about 3 ft. 8 in. in diameter, which would give 36 ft. 8 in. for their height. In the interior of the cella on either side was a row of columns of smaller size, on which probably rested a second row, as at Pæstum, to support the roof, and a gallery, the stairs to reach which are at the further end of the temple, as also three small chambers for the priests. The painting of the interior is not remarkable: the floor is paved with mosaic.

The Prisons on the right are approached by an archway in brick, formerly covered with slabs of marble. These prisons consist of dungeons without light, in which skeletons were found with their leg-bones encircled in iron shackles or stocks.

The Temple of Venus stood in a large area, 180 feet, by 75 feet, surrounded by a wall and portico. The columns of this portico were originally Doric, but afterwards altered into Corinthian by successive coats of stucco, an anomaly which I will explain further on. The walls of this portico were decorated with a series of paintings on a black ground, representing architectural scenes, landscapes, and figure subjects. The temple itself stood upon an elevated basement; had a portico of four columns in front, and two deep; and a peristyle round the cella, which latter was very small. There was an inscription in it, stating that "Marcus, Holconius, Rufus, and Caius, Ignatius Posthumus, decimvers of justice for the third time, by a decree of the Decurions, bought again the right of closing the openings for 3000 sesterces, and took care to erect a private wall up to the roof of the incorporated Venereans;"—the proceedings of that corporation, I suppose, being of such a nature that it was wise to conceal them from the public gaze.

The Basilica, or court of justice, is the largest building in Pompeii, of an oblong form, and measures 220 feet by 80 feet. It is entered through a vestibule, by five doorways of masonry, in which grooves have been cut for the insertion of wooden door-jambs. From the vesitbule the area of the Basilica is reached by a flight of four steps, leading through principal and two side doorways. The roof was carried by a peristyle of twenty large Ionic columns, built in brick and tufa, covered with stucco. The centre was probably open to the sky. At the further end of the building, on each side, are two square chalcidica; in the centre, the tribune for the judges raised on a basement, and approached on either side by steps. It was decorated by columns, detached and semi-detached; between the latter were spaces for cupboards, in which the robes or records were kept. There was a gallery round the peristyle, reaching up about half the height of the Ionic columns, with a railing between them, to prevent persons falling over.

The three buildings at the south end of the Forum, opposite the Temple of Jupiter, are similar in plan; two of them are supposed to have been places of assembly for magistrates; the third is an ærarium, or treasury.

The Chalcidicum, or Cryptoportico, of Eumachia is the next largest building to the Basilica; it is supposed to have been the Exchange of the cloth merchants. The interior was surrounded by a double gallery of forty-eight very beautiful columns of white marble (only one of which, broken, has been found); a chalcidicum, or enclosed apartment, at the further extremity; and a cryptoportico (a gallery in which the spaces between the columns are walled up and pierced with windows). Behind the chalcidicum was a niche, in which stood a statue of Eumachia, at whose expense the building was erected. The Temple of Mercury now serves as a Museum for all those objects found in the excavations, and not taken to the museum at Naples. The house of the Augustals, or Pantheon, as it is called, from the twelve pedestals in the centre of its court, in which it was supposed where the Dii Consentes, though from the numerous culinary paintings on the north wall, and the large collection of fish-bones and other fragments of food found in the sink in the centre, it would seem to have been devoted more to banqueting than to religious purposes; and, indeed, its contiguous position to the Forum would point it out as a very convenient place for a large tratteria or restaurant; the twelve rooms on the south side being private dining-saloons. It is a spacious building, with entrances on three of its sides, the one from the Forum decorated with columns and niches with pedestals for statues. This completes the list of the monuments round the Forum, and we may look upon them as the most important of those in Pompeii.

The triangular Forum, adjoining the large theatre, in the smaller part of the town, has a portico of ninety Doric columns round two of its sides. It is entered by a propylæa or vestibule, of eight Ionic columns, which, when complete, must have been one of the most beautiful features in Pompeii. The Temple of Hercules in this Forum is the most ancient building yet discovered here, its capitals, columns, and general construction resembling more the temples of Pæstum than any of the other temples in Pompeii: from its ruined state it is difficult to define exactly its plan; it is 120 feet by 70 feet wide.

The great or tragic Theatre is placed on the south side of a hill of tufa, in which the steps or seats are cut. It was semicircular, open to the air, and lined in every part with white marble. The seats faced the south, commanding (as in all these ancient theatres) an extensive view, so that the visitor, if tired with the performances, could at all events solace himself with the enjoyment of the fine prospect before him. The walls of this theatre were never entirely buried, and the stage was covered with so slight a deposit only, that here (as, in fact, probably in the greater part of the most southern portion of Pompeii), the decorative parts, such as marble, statues, &c., may have been easily removed after the eruption. The general audience entered the theatre by an arched corridor, on a level with the colonnade of the triangular Forum, and descended thence into the cavea by six flights of stairs, which divided the seats into five wedge-shaped portions or cunei. The space allotted to each was 1 ft. 3½ in., so that from calculation the theatre would accommodate 5000 persons. A separate entrance and staircase led to the women's gallery, which was placed above the corridor just mentioned, and divided into compartments or boxes. It seems also that they were protected from the gaze of the audience beneath by a screen of iron wire. In the lowest portions of the theatre, with special entrances, and separated by a low parapet or balustrade, was the præcinctio,—what we should call the pit or orchestra stalls, reserved for the nobles, Augustales and patricians. The level space in front of the reserved seats was destined for the magistrates, whose seats, the bisellia in bronze, with purple cushions, were brought by their slaves. There was also some distinction made between the middle and lower classes, the latter occupying the higher range of seats, and being divided into their respective trades and occupations. The stage or pulpitem is a long narrow platform, with seven niches in the front of the wall which carries it, in which it is supposed the musicians were placed. The proscenium was decorated with columns, and niches between them for statues, with three doorways, the centre one larger than the others, and only entered by the important characters. Their scenery was very simple, either a door swinging on a centre axis or a triangle, the one having two, the other three different views represented on it, its position being in the central doorway. Behind the stage was the postscenium, where the actors' rooms were placed. The exterior of the upper wall round the theatre still retains the projecting stone rings for receiving the poles of the velarium or awning, which on special occasions was spread over the theatre.

The small theatre adjoining is supposed to have been used for musical performances. It is also semicircular, and similar in arrangement to the other except that a portion of the circle is cut off on either side by walls continued from the side of the stage. The style and execution of the work are very inferior to the other, which is explained by the fact of an inscription, stating that it was built by contract. It seems to have been permanently roofed in, and accommodated 1500 persons.

Adjoining the theatre is a large forum, surrounded by a portico of columns, supposed to have been occupied by the soldiers, from the large amount of armour discovered. In the various rooms round these were two floors, the officers occupying the first floor. Inside one of the entrance-gates, also, were found the skeletons of thirty-four soldiers,—the guard, probably, called out on the night of the eruption. Sixty-three skeletons in all were found in the barracks,—more than in all the rest of Pompeii.

In the south-east angle of the city walls is the amphitheatre, intended for gladiatorial shows, the chase, and combat of wild beasts. It was here that the people were supposed to have been assembled when the grand eruption took place. From the number it would accommodate (10,000) and the interest taken in these shows, it is probable that more than half the inhabitants were there. From the sharpness of all its mouldings and little wear visible on the stone-work, it is probable that this building was erected not long before the destruction of the city; and, from the absence of the greater part of its stone seats, that access was had to it after the eruption. Its form is elliptical, 430 feet long by 135 feet wide. The masonry of the walls is of the *opus incertum* kind, and also of bricks placed diagonally after the Roman fashion. The interior contained twenty-four rows of seats. There were separate entrances in different parts of the theatre, the patricians, nobles, and magistrates, as usual, occupying the lower ranges, the plebeians the upper, and the women the boxes. At each end of the ellipse were entrances into the arena, for the admission of the gladiators and wild beasts, and removal of the dead.

Various inscriptions announcing displays in the amphitheatre are found on the walls in the city; one, more especially of them says that "On the occasion of the dedication of the public baths there will be a chase of wild beasts, athletic contests, sprinkling of perfumes, and an awning." The value of an awning will be easily appreciated by those who know either what the heat of an Italian sun is, or the deluge of an Italian rain. It has been a matter of some controversy how a temporary covering could be stretched over so large a space without any intermediate props. The stone rings existing on the upper portions of the exterior wall round the theatre gives me the reason to suppose that *they* were intended to hold and support the wooden masts to which the ropes carrying the awning were attached; there must have been considerable difficulty in keeping the awning stretched sufficiently tight, and we find that on windy days it was impossible sometimes to stretch them. As to the sprinkling of perfumes, Seneca tells us that "the perfumes were disseminated by being mixed with boiling water, so that the scent rose with the steam and became diffused throughout the building." Rimmel's patent vaporizer, therefore, introduced three years ago at the pantomimes in all the chief theatres of London, was by no means a novel idea.

The Temple of Isis is a small but interesting building, standing on a basement in the centre of a court, round which is a portico of Corinthian columns, in brick, covered with stucco, and painted. In one corner of the court is an ædiculum with a vaulted roof, and pediment covering the sacred well of lustral purification, to descend to which there was a narrow flight of steps. Near it was an altar, on which were found the burnt bones of victims. On the south side of the enclosure were the chambers of the priests and a kitchen. In one room a skeleton was found holding a sacrificial axe, with which he had cut his way through two walls to escape from the eruption, but perished before he could penetrate the third. In another room a skeleton was found with bones of chickens and fish, egg-shells, bread, wine, and a garland of flowers, as if he had been beguiling away the last moments of his life merrily. Many other skeletons were found in the enclosure, testifying to the belief in the power of their deity.

A flight of steps leads to the temple, the front of which is a portico of six Corinthian columns, with niches on either side of the entrance to the cella, the interior of which is small; the entire width of the back, occupied by a long hollow pedestal for statues, having two low doorways at the end near the secret stairs, by which the priest could enter unperceived and deliver the oracles as if they proceeded from the mouth of the goddess herself.

Public Baths.

Two large establishments have been found in Pompeii. They are based on a similar system to the so-called Turkish baths lately introduced in this country, and are remarkable for their admirable distribution.

The establishment first discovered behind the Forum is divided into three portions. The first contain the furnaces and the fuel; the second, the baths for men; and the third, those for women. The two sets of baths were similar in arrangement, both heated by the same furnace, and supplied from the same reservoir. Each set had its apodyterium or disrobing-room, its frigidarium, tepidarium, and calidarium, and court with portico to the men's bath, only these latter were the largest and most rich. The apodyterium has seats of lava on either side. The clothes were hung up on pegs, the holes to hold which are still visible. The roof is vaulted in stone and rubble work, faced with stucco, and painted. It was lighted at one end by a window furnished with small panes of glass, ground on one side, pieces of which were found on the floor. A cornice runs round the room, under which is an arabesque frieze in relief on a red and blue ground, composed of griffins, lyres, vases, dolphins, &c. A small recess at one end of this room is supposed to have been a wardrobe: at the opposite end is the entrance to the frigidarium, a room circular on plan, with a large cold-water bath in the centre, 12 ft. 10 in. in diameter, and 2 ft. 9 in. deep. The chamber is covered with a conical-shaped roof, painted blue, the light admitted by a window in the side of it near the top. The walls are in stucco, painted yellow, and have four semicircular niches, in which are seats for the convenience of bathers. The cornice is decorated with bas-reliefs in stucco, on a red ground, representing cupids and warriors engaged in a chariot race. The tepidarium, or warm bath, is entered from the frigidarium. It has a barrel-vaulted ceiling stuccoed, in low relief, with figures of flying genii and other ornaments, relieved on coloured ground, in medallions and panels. The more remarkable portion of the decoration, however, is the series of niches divided by terra-cotta figures, representing Telamones or Atlases, who support the cornice. These figures and niches are at a height of 4 ft. 6 in. from the ground. The figures are about 2 feet in height, stand on square plinths, and are similar in form to the giants of the temple at Agrigentum, which are supposed by Mr. Cockerell to have carried the roof. The object of these figures at Pompeii was simply to ornament the divisions of the niches, which we may suppose contained either the robes or the ointments and perfumes of the bathers. A brazier for coals, and two seats, all in bronze, were found, and still remain, in this room. The windows were awkwardly contrived. We next enter the vapour-bath or calidarium: it terminates at one end with a semicircular niche, containing a marble basin or labrum, 5 feet in diameter: at the other end is a hot-bath, 12 feet long and 2 feet deep, in white marble. The ceiling is a barrel vault in brick, covered with stucco, and ornamented with a series of transverse fluting in relief. The walls are decorated with pilasters. The walls and floors in this room are hollow, to admit of the easy circulation of the hot air from the furnaces. The floors were of similar construction as those found in the Roman villas in this country, being carried by a series of small pillars or piers formed of tiles, 1 ft. 5 in. in height and about 18 inches apart. The walls are formed of tiles, held by cramps of iron, at a distance of 3 inches from the main wall, by means of small hollow pipes attached to these tiles, through which in fact the iron cramps pass. The women's baths are arranged on a similar system, being somewhat smaller and less rich in their decoration.

The second establishment of baths, discovered in 1858, have a very large open court or palæstra, surrounded on three sides by a portico of fluted columns. The walls of the three sides under the portico are covered with paintings; and on the fourth side, there is decoration of a similar design, but executed in stucco relief. The baths were arranged and warmed on the same principle as the others.

(To be continued.)

THE APPLICATIONS OF GEOLOGY TO THE ARTS AND MANUFACTURES.

The following is extracted from a course of lectures now being delivered by Prof. Ansted at the Society of Arts:—

Professor Ansted commenced by stating that he proposed, in these lectures, to introduce the subject of the various practical applications of geology. He was aware of the difficulties; for, on the one hand, the facts were so numerous that, if merely enumerated and tabulated, they could not all be placed before his audience in the time at his disposal; and, on the other hand, if he were to generalise without facts and statistics, he could not expect that the great importance of his conclusions should be appreciated. He considered that an account of the working out of the great theorems of geology, and their bearing upon agriculture, architecture, engineering of all kinds, and mining of all kinds,—their influence on the progress of the arts of construction, and on the discovery of the material of which things are constructed, could not want interest, and need not be useless because it was brief. In treating of the applications of geology, it would be convenient to take advantage of certain natural divisions which the subject offers. The earth was both the place itself on or within which everything was done, and it yielded all the material by which everything was done. We had to employ the earth as it was presented to us by nature, and to do so we had to discover and remove from the earth the means of using the same earth to advantage.

On the applications of geology, that which had reference to agriculture was the one to be considered in this paper. It was one involving many details and many principles. On the part of those who entered on the subject, a certain knowledge of geology must be presumed, but the lecturer thought it well to lay down in a few words, in mere outline, a statement of those facts that were chiefly concerned in its reduction to the use of common life. The surface of the earth, in the cultivated parts of a country, consisted of vegetable soil. In parts where the soil was barren this might be sand or stones, but it concealed the rock. In a fertile district only a very small proportion of the surface exposed the rock to view. In England, almost everywhere on the east side of the country there was soil of some kind; while on the western extremity, there were large tracts of barren rock. Every country had its own *facies* in this respect, and even where soil existed, its thickness and general character were very variable. Whatever the thickness might be, however, there was always a termination to the soil, and below it was a subsoil partaking of a mixed character, between soil and rock, while below the subsoil was the rock, often exposed in quarries and railway cuttings, or in fragments brought up when water was sought for. Even the channel cut through by a stream, however small, would often be found to give a geological section. Rocks were of various kinds, but the varieties might be included within certain general and familiar terms. Such were limestone, sandstone, clay, granite, basalt, slate, &c. Mixed fragments of these formed gravel when loose, and conglomerates or pudding-stones when cemented together, More minute fragments ground to powder were sand. Of these some were stratified, others unstratified. So, again, some were aqueous, others igneous. Others, again, and these were very numerous, might or must have been formed with water, but were now so far changed as to have lost their aqueous character. These were metamorphic. Limestone was an aqueous rock, and stratified. Basalt was an igneous rock, and might or might not be in strata. Slate was an aqueous rock, but metamorphic. Granite was metamorphic, and generally unstratified. Stratified rocks were generally tilted, and it was even possible that beds once horizontal might be actually inverted, and made to dip the wrong way. Rocks occurred in series. Often a multitude of stratified rocks were found in the same district, some of them being much more tilted than others. Stratified rocks were often interpenetrated by those that are metamorphic or igneous, but sometimes the metamorphic and igneous would alternate with the aqueous. Such were some of the simplest and most significant facts of geology bearing on those practical questions to be considered in these lectures. Rocks were the mineral constituents of the earth beneath any vegetable soil that might have accumulated upon them. They would yield to the chemist a ready account of their composition, and to the student investigating them for that purpose, a clear outline of the mechanical changes they had undergone; while they were often sufficient to enable the geologists to determine a complete outline of events and a history of changes that may have taken a long time to complete. Owing to the mixed origin of rocks, it had happened that most rocks were broken and fractured, the cracks being filled up more or less completely with minerals, generally crystalline.

Every kind of vegetable soil was once rock, which had been broken down by degrees into fragments, until at last it was reduced to mud. The part of this process performed by the atmosphere was called weathering. Wherever rock was exposed to the air, it became weathered; and weathering meant ultimately a reduction to fine powder. On granite or quartz rock, a group of small lichens was seen to grow. These were insiduous enemies, as, although they derived their nourishment chiefly from the atmosphere, and might be thought even to protect the exposed surface from the weather, they paved the way for destruction. That which they separated from the air became a brown pulverulent mass, or *humus*, which afforded nourishment to larger individuals of the same tribe. Mosses succeeded lichens, and small crevices received their roots. Once inserted, these roots expanded, splitting asunder the rock. Other roots were thus enabled to penetrate yet further; and after a time the mosses were followed up by heather, grasses, and small shrubs, until at length there was attained a sufficient thickness of soil to enable trees to grow, thrusting down their rootlets in the crevices and making room for the admission of rain. Then frost coming, rending asunder the rock, which would fall into the valleys below, spread over the surface and being lost sight of, being washed away by the rain. In certain soils the underlying rock was found *in situ*, in angular fragments, and recognizable; elsewhere the fragments were water-worn, and belonged to some distant mountain or hill. This transported material was more common than the other, for water had everywhere been at work. Thus alluvial soils were formed. The solvent power of water was a very important agent in weathering. On detached fragments of limestone, water and vegetation together acted as a drill. Of sandstones it dissolved the calcareous cement, or even the silica itself. Thus in a mixed rock, as basalt, great differences of composition existed between an unweathered and a weathered specimen, and in a particular case referred to 65 per cent. of the soluble alkalies had been removed, 28 per cent. of the alkaline earth, nearly 20 per cent. of the silica, only 2½ per cent. of the iron oxide, and no appreciable quantity of the alumina. Productive soils were composed partly of mineral substances and partly of certain products of the decomposition of organic bodies. This latter portion was called *humus*. It consisted largely of carbon, and carbonic acid was mixed freely with the water that passed through fertile soil. Humus was not generally present in soils in large proportion, but was abundant in peat and moor soils.

The mineral constituents of a soil were of two kinds: the one kind we might call earth, as being a disintegrated mineral substance, the other consisted of fragments of the rock from which the earth was derived. The latter we might call stones. The former rendered the ground arable; the latter increased the bulk of the soil and facilitated the action of rain and frost, but contributed nothing to nutrition. Clay, lime, and sand, formed the staple of all rocks, and were the ingredients of chief importance in every cultivable soil. Clay was a silicate of alumina, capable of retaining a large quantity of water, forming with it a tenacious, compact, sticky paste, which was almost impermeable to water. Hence soil containing much clay was heavy and difficult to work, remaining wet when soaked, and caked at the surface, allowing the water to descend very imperfectly. Cold and wet places were formed underground when clay existed below a good vegetable soil, and the roots of trees and plants reaching this water were poisoned. Wet clay would contract on drying, cracks forming in it after drought. The changes that prepared a soil for sowing were then checked in such material, or were only enabled to come about slowly. Frost would break up the clods, and sand improve the quality; but a deep clay soil was very difficult to improve. Mechanical admixtures with ashes and soot, as well as with sand, were suitable to such soils. Clays contained much potash, some phosphoric acid, and lime. They would also absorb ammonia and aqueous vapour from the atmosphere, and fix the ammonia very effectually. They were thus regarded as powerful and rich. When slightly burnt they became mellow. In England clay lands had been effectually improved by various methods, and had become extremely valuable and fertile, especially for wheat crops. Drainage opened the way for the permanent improvement of clay soils. Clays were largely derived from felspars. Granite, gneiss, basalt, clay-slate, and other metamorphic and igneous rocks yielded little else than clay soils. Loam was clay mechanically mixed with sand. The quantity of free silica that might exist in a soil without removing from it the usual characteristics of clay was enormously large.

Sand was the least changed of all rocks by weathering. Sandstones were changed by the destruction of the cement that holds them together, but the actual particles changed only by mechanical abrasion. Sand was an accumulation of granules of quartz, lying loosely beside one another, leaving abundant interstices admitting the free passage of water. Water was only retained in sands near the surface, in small quantities. Light soils, containing much sand, had a hot, dry nature, giving up moisture rapidly during warm weather, and being readily heated by a summer sun. So again, these soils were active, but soon exhausted. When sand was present in an exceedingly fine mealy state it approached clay in its properties, forming a dense compact mass, and holding water. This transition was a very curious fact, and one often insufficiently regarded. Common limestone was a carbonate of lime, exceedingly soft, and readily acted on in the state of chalk, but harder and more stony in the oolites and other building stones. Limestones would work up into soils red in colour, and cracked and broken by weathering near the surface. Magnesian limestone consisted of a carbonate of lime and magnesia, the proportions being variable. It was less capable of supporting abundant vegetation than common limestone. All limestones were permeable to water, and contained a considerable per-centage of it. Chalk was especially absorbent, and acted like a sponge. A calcareous or lime soil was soft to the touch, standing in this respect midway between clay and sand. It would absorb and retain water, but would not become sodden. Its tenacity was greater than sand, but less than clay. It would shrink much less than clay, but would not crack. It would diminish the tenacity and humidity of clay soils, rendering them more porous, more accessible to air, and warmer. Where, however, lime greatly preponderated, the soil was poor and hot; but these characters were readily altered by the admixture of clay and humus. Every soil would support some vegetable growth, much of the difference depending on the mechanical condition of the soil, and much on the chemical composition. Both were due to the underlying rock.

To produce a productive soil, in the first place, certain conditions must be avoided. First, too great cohesion. A soil, otherwise productive, might be rendered unproductive if washed by rain into hollow bottoms, where it would cake into a solid, impenetrable mass. Secondly, want of cohesion. A soil might be too coarse, too loose, and too open. Thirdly, poisonous ingredients. This cause was rare, but it existed. The salts of lead and copper were absolutely poisonous in all proportions. Sulphate of iron was also poisonous, and alum might be regarded in the same light. Lastly, the excess of some nutritious ingredients. Thus common salt was used as a mineral manure, but salt water would entirely destroy vegetation. Mineral acids also interfered with growth, and would destroy vegetable life, if in too large proportion. To make a soil productive, it should possess, first, a soft consistence, unchanged by the operations of tillage. In the next place, the soil must furnish the plant with food essential to its existence in a digestible form. Among the important mineral constituents of a soil were phosphoric acid, potash, lime, and magnesia. The quantity of these was variable, but the following statement of the limits would be useful as a guide, being given on the authority of Dr. Stöckhardt, a Saxon chemist:—

An Acre of Land, six inches deep, would contain about:—	Maximum.	Minimum.	Mean of predominating Rich Soils.
	Pounds.	Pounds.	Pounds.
Phosphoric acid	12,000	150	2,500
Potash (total quantity)	53,000	1,500	22,000
Soluble potash	15,000	750	3,500
Lime and magnesia	145,000	900	30,000

This estimate would show the relative importance of these substances. The most important was phosphoric acid, for without it nourishing food could not be grown and ripened. Of other substances sulphuric acid must be present, but of it there was generally no want. Silica also was essential, and was always present. To learn the proportion needed we must refer to the constituents of the ashes of plants. These would show that some species contain in the ashes of one thousand pounds of dried plants only two pounds of lime and magnesia, half a pound of potash, and only a quarter of a pound of silica. Of meadow grass, however, the ashes contained sixty-four times as much phosphoric acid, thirty-four times as much potash, four times as much lime and magnesia, and eighty times as much silica, as in the case of coniferæ; while wheat contained the same proportion of silica as grass, but much less phosphoric acid, potash, lime, and magnesia. Particular soils were thus favorable for certain crops; forest land that had been so from time immemorial, and was put under another cultivation, was rich; certain soils, unfavourable for particular crops, might once have been the contrary.

A productive soil should be composed of nearly equal parts of the three earths, sand, clay, and lime; it should contain decomposing vegetable and animal matter; it should imbibe moisture, and give it back to the air without much difficulty; it should have depth sufficient to permit the roots of plants to sink and extend without coming to rock, to water, or to some injurious earth; the subsoil should be moderately porous, and should be able to improve the soil by mixture with it. The proper proportion of the various earths might vary from 50 to 70 per cent. of siliceous matter, 20 to 40 per cent. of clay, and 10 to 20 per cent. of calcareous matter. The earth would bear a constant succession of crops of the same kind, if the mineral ingredients removed by one crop were supplied in the same state from year to year. But this could only be done as the result of a nice calculation, and by careful and systematic farming. As a remarkable instance of the successful use of mineral manures in rendering an ordinary soil capable of bearing, the lecturer quoted the experiments carried on at Rothamsted by Mr. Lawes and Dr. Gilbert.* The general result was that the average annual yield, without manure, was much the same over the whole period of twenty years; that where ammonia salts and all mineral constituents were liberally supplied every year the produce of corn increased and that of straw somewhat diminished; and that where an excess of every constituent required by the crop was annually supplied by farm-yard manure, the rate of increase from year to year was not so great during the later as during some of the earlier years.

Analyses of soils were very suggestive. The lecturer mentioned the component parts of some extremely rich soils, but he pointed out that few ordinary soils contained within them such great natural resources. Many that were very valuable under careful management and continued culture, would be almost valueless if left to themselves. The treatment that would best succeed in improving a soil must depend on the subsoil, the climate, and the facilities that exist for obtaining at a reasonable cost the required mineral manures. Among mineral manures the most important were those which supply phosphorus and nitrogen to the growing plant or ripening seed. These were especially necessary for food plants. The want of nitrogen was usually supplied by animal manure; but this was costly, and not always obtainable at the right time in proper quantity, and in the best state. Nitrate of potash, or saltpetre, was known to be a highly efficacious substitute, as well as *cubic nitre*—a nitrate of soda, of which very large quantities were obtainable. This material appeared to be the best and readiest means of communicating nitrogen to growing plants. It was now many years since attention was directed to the phosphates of lime from Estremadura, in Spain; and Dr. Daubeney, accompanied by Captain Widdrington, undertook to decide whether it could be economically worked and conveyed to England. They found a bed consisting of several bands of tolerably pure phosphorite. The thickness of the purer part was about 3 feet, and it was traced on its line of outcrop for about two miles, but the distance from any place at which it could be shipped for exportation, and the cost of transport, rendered its existence useless for practical purposes. Other places were mentioned where this substance had been obtained. Limestone and gypsum were occasionally used as mineral manures. Much more usually, marling, manuring with mud, and warping, or bringing on the surface muddy water, and leaving it there to deposit a slime, were resorted to.

Another important department of practical agriculture was drainage. It was impossible to exaggerate the importance of water, but it was desirable to regulate its application, and remove it when in excess. Drainage performed this by acting both upon and below the surface, and allowing the water to run off by natural channels. The effect of ploughing was to disturb the ground and expose it to the air, but it was not till drain-pipes were laid that the soil could be said to be available for high cultivation. Drainage was chiefly important in heavy clay lands. Geological maps were most useful in regulating draining operations.

ON NATURAL AND ARTIFICIAL SPRINGS, &c., IN CONNECTION WITH GEOLOGICAL STRUCTURE.

Professor ANSTED remarked that a supply of fresh water is a matter of such extreme importance that every inquiry connected with it is well worthy of attention. It is connected with geology, for the conditions under which water exists in the earth depend on the arrangement of rocks and the facilities for circulation among and between them. He proposed to point out the great facts on which water-circulation and water-supply depend, and enable his audience to understand and appreciate the efforts made to obtain ample supplies when required. The source of water is the ocean; the means by which it is transferred from the ocean to the land is the atmosphere; and the circulation of water through the earth is

* See Journal R. Agricul. Soc., vol. xxv.

the fact to be borne in mind in all investigations concerning water. Of the rain that falls a large proportion is attracted to the summits and flanks of mountain-chains, to upland valleys and lofty plains; the spots of heaviest rain-fall have the sea at no great distance, and winds blowing more frequently from the sea than from the interior of the country. Much rain reaches the earth on slopes looking towards the sea, and a large quantity of water is conducted by natural channels to rivers, and across low lands to the ocean. But of a large district only a small proportion consists of river-courses, whilst the rain falls on the whole surface. The soil becomes wet, the subsoil behaves in like manner, and moisture reaches the underlying rock. Of the rocks some are sands, sandstones, or limestones, and others fragmentary rocks. These allow water to enter, and give back the water at need. Others are impermeable strata, between or amongst which are beds shutting off water. Such are clays. All rocks contain water. Granites and compact marbles, in their driest state, hold from ·4 to 4 per cent. by weight; and, as a cubic yard of such stone weighs two tons, each ton of the least absorbent rock will contain a pint of water. The water held by common loose sea-sand amounts to at least two gallons in a cubic foot. In ordinary sandstones nearly half that quantity can be contained; and in best sandstones five pints of water are contained in each cubic foot. Thus in an area of such sandstone, occupying ten square miles, and ten yards in thickness, the quantity of water contained is from four to five hundred millions of gallons. This would fill a reservoir of 100 acres to the depth of 10 feet. But sandstones are rare without bands of clay separating their water contents into sheets, and owing to faults and vertical bands of compact mineral a sandstone district is broken up into boxes, each one of which is independent to some extent of the rest. Sandstones have also been tilted, and stand at a considerable pitch, tolerably uniform over great distances. Some varieties of sand-rock, passing into pudding-stone on the one hand and quartzite on the other, contain no water, but even in such rocks there are fissures and cracks wherever there is an exposed surface. Into these water penetrates. Of limestones the least absorbent hold four pints in the cubic foot, while a cubic foot of Bath stone will absorb a gallon; and some magnesian limestones twelve pints. A cubic foot of soft chalk will hold two gallons of water, or as much as loose sand, taking up half its own bulk of water and yet hardly appearing wet. By pumping a large quantity of water may be obtained from chalk, for its acts as a sponge, the water sinking to the bottom. In most limestones the water does not come away by pumping, being kept back by friction, as well as by capillary attraction. Limestone is more available as a water-bearing rock than sandstone, being more cracked and fissured at all depths. It is acted on by water, both mechanically by wear, and chemically by becoming dissolved. The cavernous nature of limestone is one of its most remarkable features, and at the intervals of strata there are spaces allowing a free passage to water, besides vertical fissures, dividing up the mass into smaller areas, each one of which has its own water system, though all communicate. Clays often contain as much as ten per cent. of water (by weight), and clay rocks, such as the varieties of schist, which are extremely numerous, are similarly constituted. Water is present in great abundance in the rocks near the surface of the earth, not only in the substance of all, but in the interstices.

Of the rain that falls upon the earth at any place not more than one-third runs off the surface and enters the sea by rivers. What becomes of the rest? Part is evaporated; part supplies life; but an ample supply enters the earth. Down natural channels the water passes; occasionally through a permeable rock, sometimes slowly, with much interference, and sometimes into cavities. It is conveyed horizontally, and rises here and there to the surface under the influence of the pressure of a column whose height has reference to the level of the spot at which it first entered as rain. This circulation is due to the natural inequalities of the land. As the rain falls mostly on mountains and high ground, and rocks are usually tilted towards the plains, the tendency of water to run down a slope in the interior of the earth as well as on its surface, insures the conveyance of ample supplies. These may exist under pressure arising from the fact that the channels formed between two impermeable rocks are closed pipes. But because the dip is not always the same as the natural slope of the surface, and that faults remove rocks to a considerable distance vertically, water will sometimes find an issue at a considerable distance; it may well up at a fault, or come out at an artificial cutting, though always at a lower level than that at which it entered. Water obtained by any of these means is called a spring. Land-springs occur in sand or gravel resting on impermeable strata, and receiving a larger quantity of rain on their surface than is carried off by evaporation or streams. The water accumulates below, instead of upon the surface. Its depth is rarely great, and it is reached by wells. The supply varies with the rain-fall, and in dry seasons fails, or gets much lower than usual. The quality of such water is liable to injury, owing to the filtration into it of organic matter from above. Wells in such localities sometimes yield upwards of a hundred grains of solid matter to the gallon.

A second class of natural springs issue on hill sides, in valleys, or on plains surrounded by higher land. They depend on the outcrop of strata which carry water, but rest on other strata that are impermeable. The issuing of springs under these circumstances is easily understood; though the phenomena may become complicated and obscure. The source of the supply may be distant, and much above the level of the point of emergence. When it issues, the water may be a considerable stream, or may drain out in a multitude of springs on a continuous line of outcrop Groups of springs of this kind are often important, dividing the irregularities of season over a considerable time, and to some extent independent of season. The water having filtered through the earth for a long distance, is fresh and wholesome. Springs of this kind may be tapped on their way to their natural outlet. The supply they bring is limited, and what is taken at any one place is taken from the general stock. It may be that the upper rock is porous, and rests on an underlying, impermeable stratum. The supply is then more abundant, but less regular. Good examples of such springs exist in the Cotswolds, where, all along the oolites with the lias, groups of springs issue. A few days after the rain most of these springs become swollen, and run freely. After dry summer weather the supply falls off. In this case the dip of the beds changes, but the main cause of the irregularity must be sought for in the fact that, though crop-springs in one sense, they are land-springs in the nature of their supply.

A third-class of mineral springs issues where the containing rocks are interrupted by faults. In this case there are several possibilities. A fault acting as a wall, because it is filled with clay, will in most cases be accompanied by a spring, though not always at the exact spot where we might be inclined to look for it. Artesian springs occur in many places, and have been obtained artificially from the earliest times. A permeable bed between two impermeable beds, crops out at the surface, and there receives the rain-fall and surface-water. The level of this out-crop is higher than that of a part of the surrounding country beneath which the strata pass, owing to their dip. The permeable bed thus presents a bent tube, and may be kept full of water under a pressure corresponding to the height at which the porous bed crops out. If, then, a well is sunk or a hole bored, the water will rise in it, not only towards, but even in some cases far above the surface, in a jet.

The chief Artesian wells, and the oldest in Europe, are in the north of France, and they seem to have spread thence through the other countries of Europe. They are sunk through the lower tertiary strata to the chalk, from whose upper beds the water is generally derived. The construction of this class of wells is easy and inexpensive. The Artesian wells of Artois date back to the twelfth century. In Italy and Germany, ancient and successful wells of this kind exist, but it is only since the commencement of the present century that they have become general in Europe. In and around Paris there were already, in 1845, not less than eighty deep Artesian wells through the tertiary strata into the chalk. The supply varies very much, but is tolerably constant in the same well. A supply of from 30,000 to 150,000 gallons per day is the common yield, and the expense of sinking is extremely moderate. The sinking for the supply of Paris commenced at Grenelle, in 1833, and continued till 1841, when water-bearing strata were reached at 1800 feet, at a cost of £15,000. The first rush of water was at the rate of nearly a million gallons per day, rising 120 feet above the surface, This continued for some time. Artesian wells are common also in England, not only in and around London, where the geological conditions closely resemble those of Paris, but at Cambridge through the gault, at Liverpool through the new red sandstone, and elsewhere. The Artesian wells of London are confined to borings through the tertiaries into the chalk, and do not include any sinkings to the greensand. The depth of most of the Artesian wells of London is less than 400 feet, and none of them are much above 500 feet. Some enter the chalk to a depth of 200 feet, or more, and therefore obtain their water to some extent from that formation; while others only reach the chalk, and obtain water from the sands. The tertiary strata pierced are rarely more than 250 feet in thickness. The water, when reached, seldom rises higher than from 40 feet to 60 feet below the level of the Thames high-water mark, and thus considerable expenses are incurred in lifting it. The wells at Cambridge penetrate the gault to the lower greensand, at a depth of from 100 feet to 150 feet. The cost is small, and the supply at first rose to or above the surface. It is now 10 feet or 12 feet below. The supply is large and steady, and the number of wells within a few square miles amounts to several hundred. The wells in the new red sandstone at Liverpool and elsewhere are also very numerous, but nowhere very deep.

The quality of the water obtained from Artesian wells is a matter of importance. Water passing through a course of strata absorbs mineral matter; but clay is capable either of removing mineral salts from water when they are already present, or yielding various salts if the water be pure;—and thus waters passing through a great thickness of clay may be either remarkably pure or very hard. Of the different minerals found in water there are some that produce hardness, and interfere with the use of the water for detergent purposes, though not otherwise injurious. The alkaline salts render water soft, and thus the large quantity of salts of soda and potash in some of the waters from deep wells does not interfere with their value for household purposes. Carbonate of lime and magnesia, on the other hand, and the salts of iron, though they render water hard, leave it well fitted for drinking purposes.

A fifth class of springs is somewhat exceptional, occurring in connection with disturbances of strata, or the presence of metamorphic rock. Such springs are charged with mineral matter and gases, including free carbonic acid gas, nitrogen, hydrogen, oxygen, and sulphuretted hydrogen gas, with a long series of salts of most of the metals. A large quantity of matter is brought by these springs to the earth's surface from the interior, upwards of 16,000 tons weight per annum of various salts being estimated as brought up to the surface from the mineral springs of the central plateau of France. These springs are thermal, or possess a temperature higher than the mean annual temperature of the place at which they emerge. This temperature varies, and sometimes reaches the boiling point. The water rises from great depths, and often in large quantities. These springs are found in all parts of the world, and at all levels above the sea, but they are usually most abundant in mountainous regions, or near volcanoes.

The flow of springs is not always uniform, but deep springs are more uniform than those which come from near the surface. For the cause of small and irregular variations we must probably look to the effect of the seasons, but there are marked periodical variations of supply in particular cases that require a more definite explanation. They are known as intermittent springs, and are almost confined to limestone districts. The river Mole, in Surrey, issuing from the chalk, is an example of this kind of spring. It appears abruptly at intervals, which are nearly regular; then runs strong for a certain period, and as suddenly stops. There probably exists in the chalk hills adjacent a reservoir, filled from the rock above, but with only one outlet, which by some accident of the stratification curves upwards a few yards before turning down again. So long as the water in the reservoir is not higher then the top of the curved part of the water-way, no water can run out, but as soon as this happens the bent tube acts as a siphon, and when it once begins continues to carry out the water till it has emptied the reservoir. Such are the phenomena of springs, natural and artificial, and such the methods adopted by nature and imitated by man to bring the water from the interior of the earth once more to the surface.

Let me now point out the application of this great subject to the supply of towns. Some arrangement that shall secure a permanent supply of water for cities is essential. For this purpose most large towns are situated on, or near, running streams. But as the town increases, the waters of the stream become reduced in quantity by the large use made of them, and deteriorated in quality. Wherever there is a large population the sewage is in excess of the demand of the agriculturist, and is conducted into the nearest running water. Thus the water of the river as it passes each town becomes smaller and more impure as the need of water becomes greater. Springs are resorted to for potable water, and the river water is only used for washing. Rain-water is collected and stored, but rain-water in a town is rendered foul by the admixture of smoke and vapours, and the supply is of little value. Means have been resorted to from time immemorial to obtain and conduct water from natural sources of supply to large cities. The Romans obtained water in this way from distant places, and conveyed it by aqueducts to the spot where it was needed. Long before the Romans, the Greeks had conveyed water over the surface in closed pipes, taking advantage of the fact that water stands at the same level if there is free communication, no matter how irregular the form and dimensions of the channel. These methods are resorted to at the present day, and with similar success. But a supply of water is not a thing that can be secured easily and without cost. It is an engineering operation for which the aid of the practical geologist must be sought. To obtain pure water for a town, resort must be had to contrivances suggested by, or adapted to, the physical condition of the country surrounding the town, and thus, while in some cases springs may be resorted to, in others rivers or canals may be used; in others, streams may be intercepted at or near their source; in others, mountain lakes or tarns may be rendered available; and occasionally the rain-fall of a limited district may be collected and stored in reservoirs, whence the water is carried underground or on the surface to a reservoir near the place where the supply is needed. Examples of all these methods may be found in the various towns of England.

There are certain limits to the supply of water from springs, even the most favourably circumstanced, which now require consideration. Chalk, or loose sand, and some sandstones, yield a large quantity of water, replaced from time to time by rain, and the quantity contained in a given area of rock may exceed the quantity required for the town on the surface. But it by no means follows that water is obtainable because it is present in the rock. The loosest varieties of rock are sufficiently close to offer difficulties to the free passage of water: and even from wells of exhaustion the quantity of water removed in a given time is not only incapable of being increased, but the rock is only drained of water within the content of a cone whose base is at the surface and whose apex is at the bottom of the well, and the area of whose base is rarely more than half a mile in radius. The two rocks that yield the largest quantity of water are chalk and soft sandstone; and in neither of these can more than a million gallons per day be expected from a single well. To yield this maximum, such wells must be more than a mile asunder. It could only be from a natural reservoir of large size, existing under pressure in the interior of a rock, that a large permanent supply could be obtained. The expense of Artesian borings, though varying much according to the particular circumstances of each case, is rarely very great. In Europe the cost of boring has rarely much exceeded 10*s.* per foot if the depth is under 200 feet, one pound per foot if from 200 to 500 feet, two pounds a foot from 500 to 1000 feet, and three pounds per foot from 1000 to 2000 feet. There are thus powerful inducements at all times to resort to this expedient. On the other hand, it must not be lost sight of that there have been some very costly instances of failure after boring to a great depth in promising strata.

When, owing to increased population, a deterioration of the quality of the water, or a diminution of the regularity of the supply, it is necessary to have recourse to some other contrivance than springs, the old Roman method of constructing an aqueduct has been resorted to. Thus, in the case of London, the "New River" was thought a great success. But opportunities of cutting off water are gradually becoming more and more scarce, while it becomes always more difficult to keep a stream clear. Such contrivances gradually cease to be applicable; and only when connected with reservoirs can this supply be recommended. But the construction of a reservoir is a very serious matter, as is known by fatal experience in some recent instances. It is not twelve months since the bursting of a newly-constructed reservoir in the neighbourhood of Sheffield produced a serious loss of life and property. Thus in this mode of obtaining a supply there are important points to be considered. I may state these as, first, the ultimate source of the water; secondly, the storing it in reservoirs; and, thirdly, the conveying it to its destination. Where there is a natural lake of pure water sufficiently large and well supplied to insure a permanent supply, no better source can exist. The cost of conveyance is often a barrier against the adoption of such plans; but the possession of a natural reservoir, always full of the purest water, is no slight matter. But if there is no lake, natural springs, if sufficiently large in quantity and good in quality, may be made use of. Thus many of the sources of the Thames are powerful enough to be worth taking for the use of London. But to this there has always been a strong objection. The quantity of water entering the sea at the mouth of the Thames is so little more than sufficient to insure a permanent stream, that it cannot afford to lose any tributary, however small. Even when a single spring can be taken, it rarely happens that the flow is so regular as to be sufficient without a reservoir. In hilly districts it is usual to take advantage of natural irregularities of the land, and select the head of a valley where a convenient space can be inclosed. Such embankments are not always dangerous; but a weak point in the stratification may be the cause of an accident, as well as faults of construction. Reservoirs are necessary where the rainfall of a district is to be collected and transferred to a distant spot. In Lancashire and Yorkshire there are several instances of this arrangement. The rainfall of the district, the form of the collecting ground, the rock of which it is composed, and the dip of the rock, are matters of inquiry, and need the knowledge and experience of a geologist. Manchester is supplied from the drainage of a gathering ground of 18,000 acres, at a distance of 16 miles from the city; Liverpool, from an area of 10,400 acres, 26 miles distant; Newcastle-on-Tyne, from 4000 acres, 12 miles distant; Bolton, from 400 acres. 4 miles distant.

The lecturer, in conclusion, gave a brief notice of the water contents of the various British rocks. The upper tertiaries of England, and the gravel, afford land springs. It is not till we penetrate the lower tertiaries, and reach the permeable sands between the London clay and the chalk, that we obtain large supplies from Artesian borings. The supply from the sands below the London clay is extremely large. Chalk contains an enormous quantity of water, distributed through the mass, though chiefly abundant in the lower part. The lines of flint favour percolation, and occasional spaces in the rock are generally full. At intervals in the chalk are beds that hold back water better than the rest. Water may almost always be obtained by sinking into the chalk to a sufficient depth. Wells sunk through chalk into the upper greensand are not always more successful than those terminating in the chalk; but the gault below the upper greensand, being impermeable, water may be expected on reaching this bed. The lower greensands are extremely wet. Large supplies may be expected from sinking to this rock, but the quantity obtainable from a single well, or from wells within a given distance of each other, is limited. The water of the lower greensand is irony if got near the outcrop, but when filtered through other beds, especially when passing through clay, it becomes more pure. Little water can be got from the Weald clay, nor is the Hastings sand to be depended on. The Kimmeridge clay and the Oxford clay are retentive, and have little value as water-bearing beds. Water is to be got between or even amongst these two bands of clay, but it depends on local conditions, and its presence cannot be assumed without proof. The Portland rock includes overlying stones and an underlying sand, the former of which holds water in crevices, the latter in its mass. The lower oolites contain water, the alternation of clays and open limestones being very frequent. The wells have to be sunk into the rock to its plane of saturation, or even through it to the clay, as the limestone does not otherwise yield a supply. Lias holds back water, so that at its contact with the lower oolite there is almost always a line of springs, and the supply is large and constant. Wells sunk into the upper beds of the lias rarely fail in obtaining water, but the quality is not good. Wells sunk through the lias obtain water from the new red sandstone. Wells sunk in the new red sandstone are almost certain of success; but, owing to the number of close faults, the quantity cannot be depended on, and the water is apt to be salt. The new red sandstone is eminently a water-bearing bed, and the numerous alternations of marl and sand render it possible to obtain water from almost all depths. The magnesian limestone is full of cavities filled with water to a certain level. In the coal measures, and in the mountain limestone, wherever there is an impermeable band between strata, or at faults, water is found. The faulted condition of the carboniferous and older rocks in England greatly affects the water capacity of the rock. The old red sandstone is a variable rock, sometimes containing much water in sandy beds, sometimes in cavities, and, at intervals, between the strata. There is generally a good store of water wherever this rock prevails. In Silurian rocks water is got from faults and fissures, which are very numerous. The limestones of this period are, for the most part, argillaceous, and hold back water. Slates, schists, and all varieties of granite, hold water only in fissures. Where there is a considerable rainfall these rocks sometimes afford large supplies. Little dependence can be placed on them, for the fissures do not communicate readily from one to another. A remarkable instance of successful sinking in granite exists in the island of Jersey, where a sinking was commenced in the solid granite, and was continued to a depth of 234 feet, all compact rock. At this depth a spring was reached which rose seventy feet in the shaft, and has continued at that level.

INSTITUTION OF CIVIL ENGINEERS.

Feb. 7.—The paper read was "*The Chey-Air Bridge, Madras Railway.*" By E. Johnson, M. Inst. C.E.

The author remarked that, the River Chey-Air presented the usual features met with in nearly all the large rivers of Southern India. The banks were generally low and ill-defined, and the bed, for almost the entire width, and to an unknown depth, consisted of clean sharp sand. For nine months during the year the bed was perfectly dry, being subject only to heavy floods in the months of May, June, and November; but, even during the driest seasons, the substratum was always charged with water to within 2 or 3 feet of the surface.

The bridge was situated on the North-West line, at a distance of 143 miles from Madras; the extreme width of the river at the point of crossing was 3360 feet, the drainage area being about 2272 square miles, and the fall of the stream at the rate of 11 feet per mile. At a distance of 20 chains above the bridge, the river separated into two distinct channels, that on the south being 1600 feet in width, and that on the north 1256 feet in width, and at the point of crossing the bank dividing the two was 464 feet in width. The highest point of the bank was 5·57 feet above the bed of the river, and 2·27 feet higher than the general level of the land for some distance on each side of the river. As it was ascertained that the highest known flood only covered the bank to a depth of 14 inches, it was determined to make this portion of the work a solid embankment, and to span the two arms of the river by distinct bridges; that on the south contained twenty-two openings, while that on the north had sixteen openings, each 70 feet span from centre to centre of the piers.

The piers were built of masonry, laid on timber platforms, placed within dams, at a depth of 15 feet below the bed of the river, the superstructure being composed of ordinary boiler-plate girders. In commencing the operations, the sand over the site of the intended dam was first removed, until the water was reached. The dimensions of the dam, 52 feet by 22 feet, being then set out, piles, 9 inches square, were driven at intervals of 10 feet, to a depth of 18 feet, the heads being cut off level with the water. The piles were secured by waling-pieces, and were strongly braced across. Close planking, 2½ inches in thickness, was next let down behind the piles, and the space around the dam was backed up with clay and grass sods, to prevent the sand from slipping in. The Picottah pumps were afterwards fixed at intervals of 3 feet along three sides of the dams, being supported on sleepers, bedded on clay, one end of each sleeper resting on the waling-pieces. Each dam was surrounded by a wooden trough, for receiving the water raised from the foundation pit, and this trough communicated with a channel, cut to a depth of about 5 feet at the commencement, and terminating on the surface at a distance of 50 chains down the river. This was rendered possible by the fall of the river, 11 feet per mile, and the lift was thus reduced from 15 feet to 10 feet. The Picottah pump was much used in many parts of Southern India for irrigation purposes, and it had been found very efficient for emptying foundation pits. It consisted simply of a balance lever, one end of which was weighted by a man walking up and down the lever, while to the other end a bucket was suspended by a long bamboo, another man standing on a staging in the dam, guiding the bucket, and filling and emptying it. The bucket was made of thin sheet iron, and was capable of containing about 5 gallons. Two well-trained men would raise on an average about 35 gallons per minute, where the lift did not exceed 9 or 10 feet. At the Chey-Air bridge, it was found necessary to use at each dam thirty-six of these pumps, worked by a gang of seventy-two coolies, who were relieved every six hours, and who raised on an average 1260 gallons per minute, the mean lift being from 7 to 8 feet.

The timber platforms were of aucha and aloopay, both close hard-grained woods; and, being entirely protected from the alternate action of air and water, it was believed they would be very durable. These platforms were 42 feet in length by 13 feet in width; the main beams and transverse pieces were 12 inches square, and over these there was a flooring of sleepers 10 feet long and 10 inches by 6 inches in section. On this flooring heavy courses of well-bedded, hard, slaty magnesian limestone, the blocks varying in size from ½ to ¾ of a cubic yard, were built in hydraulic mortar, and well grouted, up to within 18 inches of the bed of the river, and therefore about 18 inches above the lowest level to which the water subsided in the sand. Above this point, the masonry consisted of a light-coloured magnesian limestone, obtained from a quarry situated 2¼ miles from the work, and which was delivered at the bridge, by a native contractor, at the rate of 5s. 6d. per cubic yard, subject to a deduction of one-seventh for bad stacking. No appreciable settlement was noti ed after the first course of masonry was laid. The piling and the timber around the dams had, in every instance, remained undisturbed; and the space between them and the masonry had been filled in with waste stone to a depth of 9 feet. The works had withstood the monsoons during three years, without showing the slightest indication of any scour; in fact, after heavy floods, no alteration took place in the bed of the river.

The total cost of preparing a single dam, with timber platform complete, ready to receive the masonry, was

Pile driving	... ...	£24 3 6	
Excavation	... ...	38 13 0	
Pumping	... ...	50 2 0	
Timber platform	... ...	37 9 0	
			£150 7 6

The bridge contained 16,320 cubic yards of masonry, executed at a cost of £18,681. The works were commenced on the 13th August, 1860, and were completed ready to receive the girders on the 16th January, 1862.

Respecting the character of the work yet remaining to be done, it was stated that it would be merely a repetition of what had already been executed in the case of several large bridges on the same line of railway. In illustration, the superstructure of the bridge over the River Cavery was alluded to, the spans and all essential particulars being identical. The girders were continuous over two spans, and were thus 140 feet in length. They were ordinary boiler-plate girders, so proportioned as to give a maximum strain of 5 tons per square inch on the extended parts, and 4 tons per square inch on the compressed parts. Each length of 140 feet was composed of three portions; the central one was 30 feet in length, and had its centre over the middle pier, while the two ends were each 55 feet in length, and extended to the centres of the two adjacent piers. The position of the joints was determined by calculation, to be about the points of contrary flexure, in various states of distribution of the load. The three pieces were joined together on a platform adjacent to the abutment; and when this was accomplished, the two girders were connected by cross bracing, and by a system of longitudinal bracing, formed by a "herring-bone" arrangement of half timbers, bolted to the under side of the cross-bearers, by which the rails were carried. It was found, by experiment, that when the ordinary T iron cross bracing alone was fixed, the vibrations of a pair of girders could be increased to about 5 inches, by the application of a moderate lateral force isochronous with these vibrations; whilst on the addition of the herring-bone bracing, it became impossible to produce any appreciable vibration by such means. For the purpose of getting the girders into their places, at the top of each pier two frames were erected, each carrying two rollers in the lines of the centres of the girders. To the underside of the latter, rails were attached, with their running faces downwards. The girders were first lifted, by jacks, from the platforms, when several rollers were fixed on the platforms, and the girders were then allowed to rest on the rollers. The girders were next hauled forward by a powerful crab tackle placed on one of the piers in advance, and so were ultimately taken to the further end of the bridge; the remainder being hauled over in succession. Having thus always two bearing points, with the centre of gravity between them, there was no tendency to tilt, and no necessity for staging or scaffolding—a material advantage in the case of rivers subject to sudden floods of extreme violence.

February 14.—The Paper read was "*Giffard's Injector*," by John England, M. Inst. C.E.

Before entering into a description of this instrument, the author alluded to what had been previously done, for raising or forcing water by means of a jet of steam, and apparatus without moving parts; including the plans of Solomon de Caus, of David Ramseye, of the Marquis of Worcester, of Savery, in 1698, and of the Marquis de Manoury d'Ectot, in 1818. It was observed that when Manoury, by the same means as Savery, had raised water to the height due to atmospheric pressure, instead of, like Savery, carrying it further by means of a steam-jet, he employed a water-jet, on the principle of Montgolfier's water ram, for raising it to the required height; so that Savery's method, though more than a century older than Manoury's, approached nearer to the apparatus under consideration.

In describing the mechanism of the Injector, the author divided the instrument into two distinct parts, by an imaginary plane at right angles to the axis, through the space between the two nozzles, through one of which the jet of mixed steam and water was forced, by the pressure from the boiler, while the other received this jet of mixed steam and water for transmission to the boiler. The instrument consisted of a cylinder, having fixed in it, below the level of the inlet, of the feed-water, a conical piece, called the "lance." Sliding in the upper part of this cylinder was a perforated tube, with a tapering termination called the tuyère, and this tube was worked by a handle and screw, by which the area of the annular passage for the feed-water, formed by the conical piece in the cylinder and the tapering termination of the tube, could be varied at pleasure, according to the temperature of the feed-water and the pressure in the boiler, as the higher the pressure the greater the opening required. Within the tube there was a solid plug, called the needle, worked by another handle and screw, and likewise having a tapering end, by which the area of the steam passage could be increased or diminished, by the less or greater extent of the insertion of the needle in the tuyère. When adjusted for work, the action of the steam-jet from the tuyère was such, that a column of commingled water and steam, called the 'sheaf,' was projected in the direction of the axis of the instrument, through the terminus of the 'lance.' In the axis of the 'lance,' and at a short distance from its end, was fixed the second part of the apparatus, consisting simply of a divergent tube, whose properties had long been known, but of the application of which no one appeared to have thought; till the inventor of this instrument availed himself of it, with so much ingenuity and success. Leading directly to the boiler, this tube was furnished with a valve, which, when the work was stopped, closed with the back pressure.

Two modifications of the first part of the apparatus were then noticed. In one, which had been supplied for a stationary boiler, the tuyère, instead of sliding with the inner tube, was fixed to the cylinder, so that it became the terminus of the steam pipe from the boiler; and the inner tube, instead of carrying the needle, contained the 'lance' and the divergent tube, and was now, when moved towards the fixed tuyère, the water adjustment, the packing between the water and the steam chambers which with the moving tuyère was needed, being dispensed with. In the other, which was a modification of the latter, by M. Turck, the water chamber was isolated by the inner tube; and the inner tube, instead of carrying the 'lance' and the divergent tube, moved independently of them, as well as of the needle; thus not only dispensing with the packing between the water and steam chambers, but getting rid of packing altogether.

The form of the 'lance' had been determined, principally, by experiment. The minimum section of the divergent tube was the unit by which the other parts of the instrument were measured and proportioned, and determined its force of injection. Experiments had given 1·3 for the orifice of the 'lance,' or nearly that of the tuyère; but at very high pressures this must be reduced to unity, the tuyère then being 1·2.

Respecting the physical properties of the 'sheaf,' it was remarked that the indraught of the feed-water was accounted for, in the same manner as the working of water bellows, or the blast in locomotive chimneys, by the abstraction of *vis viva* due to an instantaneous change of velocity. The feed-water mixing with the motor steam, which it partially condensed, resulted in a sheaf made up of minute spheres, which, if received into a glass vessel, disappeared with the cessation of motion. Experiments proved that the velocity of the sheaf, so composed of spherical particles, was greatly in excess of that due to the quiescent force of the water in a boiler which it had to overcome. When leaving the boiler at a temperature due to its pressure, the steam escaped from the tuyère, and penetrated a liquid whose temperature was much less, a sudden change took place—an instantaneous conversion of heat into work. It was easy to express, algebraically, the useful effect resulting from this work: it was the force of projection with which the sheaf in each time-unit was moving; it was the dynamic quantity which would be turned into useful work. This quantity had for expression, the incorporation of the mass with one-half the square of its velocity. With this force of projection, the sheaf after leaving the 'lance,' and traversing the space in communication with the atmosphere, encountered the quiescent force of the water in the boiler, the moment it passed the minimum section of the divergent tube, the slight taper of which permitted, with minimum friction, the expansion of the sheaf around its axis. As this result of the back pressure from the boiler took place, the velocity of each element being converted into pressure, the sum of these effects represented the total energy of the sheaf. In other words, its pressure, in every successive cross section of the divergent tube, became greater, till at the end it attained the maximum, and entered the boiler. From the moment onward motion began and the work of injection took place, then, from the contraction of the sheaf in the 'lance,' to its expansion in the divergent tube, a simple phenomenon of liquid fluid, as in a conduit, was produced.

The author next alluded, in detail, to a table showing the conditions of working the Injector for which he was indebted to M. Turck, of the Western Railway of France; and gave another table exhibiting the quantity of water injected per square millimètre of the minimum section of the divergent tube, in gallons per minute, by instruments of four companies, according to experiments made by the "Compagnie de l'Ouest."

The mode of working with the Injector on the Western Railway of France was, according to M. Turck, as follows:—Steam was maintained to the indicated pressure of 9½ atmospheres, going down inclines the boiler was filled to the maximum water level, and it was supplied during stoppages at stations, care being taken to arrive with low water. In those stations where the engine had to remain some hours before starting the steam was at 2, or at most 3 atmospheres, and as soon as the engine was shunted, the Injectors were set to work to fill the boiler, using up the steam, which would, with pumps and without a donkey engine be wasted, to 0. There were engine-men who when the steam was blown off, which seldom happened, were enabled to heat the water in the tender, and who by feeding on the inclines and at stations, saved, as compared with the same boilers fed with pumps, but without a donkey engine, a kilogramme and a half of fuel per kilometre.

The test of the Injector appeared to be its comparison with an apparatus such as Mr. Beattie's, which abstracting its first cost, and that of maintenance by utilizing the heat of the exhaust steam, and by delivering the water at the boiling point, was asserted to effect a saving of fuel to the extent of 13½ per cent. as compared with any process other than that of the Injector, delivering feeding water at the temperature of 50°. The apparatus was described, but it was contended that this method did not effect a saving of more than 9 per cent. To set against this there was the excess of first cost and of maintenance, the greater liability to accidents and the increase of back pressure. These were deemed to be so considerable that most railway companies, both at home and abroad, now adopted the Injector for all new engines.

It was observed that the application of this instrument as an elevator opened a wide field for its employment, and in conclusion a list was given of all that had been published in France and in this country relative to the Injector, which, with the exception of the information furnished by M. Turck, had formed the data on which the paper had been prepared.

THE CONSTRUCTION OF THEATRES.*

By Warrington Taylor.

The construction of theatres, from their scarcity, occupies the attention of architects less than any other class of building. It is well that it is so; for the habits of a country truly domestic do not demand amusement away from the fire-side. In southern countries matters are different; people live more out of doors, and take a deeper interest in stage performances. In this paper it will become necessary to point out the differences between the requirements of a foreign theatre and an English one, and therefore we shall have opportunities of judging our peculiar wants. Such a theatre as the new Opera House in Paris, which is essentially a Government establishment, would be wholly useless in England, where a theatre is a private speculation. Concerning the plans, which are deposited in the library here, I shall remark that they do not show any originality of arrangement, nor do I see anything practical in the plan. I find it an exaggerated and badly proportioned copy of Munich, with which it will not compare for compactness. Modern architects imagine that a theatre is an intensely difficult building to carry out, and consider themselves very important men when they have one to build. For my own part I cannot see that a theatre is a difficult building to arrange; it requires only common sense, and attention to the absolute wants of the place. It requires none of the higher faculties of the architect—viz. poetry. A theatre is only used for a few hours every evening; very few people live in it, only fireman, hall porter, and housekeeper. The arrangements are strictly practical, just what are wanted for the few hours it is used.

The great law to be observed in building a theatre is this: whenever two passages meet, by which an exit takes place; from that point on, the passage should be double the size, in order to let the double crowd pass easily down. Your passages and staircases should be direct, never to give your audience a chance of choosing by which way it should go down; they do not then hesitate or stop the way at all. In case of fire, how important this is we all know. In the new Opera House in Paris the plans seem to me to be most deficient in this respect; the large halls and staircases will give rise to much lounging about. By this rule of doubling the size of the passages where they meet, you must arrange the width of the lobbies and other parts. This appears to be the truest principle of arriving at a comfortable and safe theatre. As regards the street, you must obviate bringing two crowds together, such as the pit and gallery, for you block up the pathway, the box people cannot get to their carriages, and the police are annoyed in their duties. Here is the importance of getting a site at the corner of a street or an open square. Two staircases to the gallery you may generally obtain, although only one would be used as an entrance. Your various tiers, if they are circles let in single seats, you must avoid bringing together into one mass, for they then congregate and do not get away. In England, however, it is most necessary to provide a proper "crush" and waiting room, where the carriage audience may wait; but the passage from this to the outside should not be crammed up by the people who are going to walk away from the theatre; I mean, you must let your foot people out clear, without bringing the two together at the very doors, and certainly not bring the foot people through the crush room. Above all things keep your pit exit away from that of the boxes. If you can arrange to let the foot people out by the side of the theatre, and keep the front for the carriages, you will facilitate the matter still more. Proper cloak rooms, with washing conveniences and water closets, the refreshment rooms, the box office, are all necessary adjuncts.

We now come to consider the form of the theatre. Everybody must know that at the side anyone sitting at the back can never see the performance; hence the sides must be kept for private boxes, which, being sufficiently large, will afford good accommodation for four people. No modern theatre can be required to hold above 2500 people; perhaps a very cheap place of amusement, with unusually large gallery and pit, may require room for 3000—lucky is the director who can fill it for any length of time. If you can build so large a house as this, no shape is as good as that of Her Majesty's—viz. the half circle continued with straight sides very slightly contracted as they near the stage; the tiers one exactly beneath the other, no one projecting beyond the other. At Drury Lane the tiers are unusually deep, from one house having been built inside the other; but this is not so good for sound. If it is a small house, an adaptation of the balcon principle must be adhered to, in order to get sufficient places. One of the best studies of this sort of house is that at Mayence, given in Fergusson's 'Handbook of Architecture.' The round corners at the stage end of the balcon at the Adelphi are very unsightly in shape; they should come sharp away from the side.

As to sound all the elaborate theories have failed to produce a perfect house. The very best theatre in the world for sound is Her Majesty's, which was certainly built without any such scientific principles. But I will explain how it is that you do hear so well in that theatre. The shape of it is like a drum, and the wall of the auditorium is flat. The brick wall ought always to be at the back of the boxes, although for safety against fire you require another wall at the back of the lobby. If the wall at the back of the boxes be only of canvas, or plastered, you cannot expect good acoustic; hangings, curtains, papers, are all against good sound. At Her Majesty's there are no projecting ornaments of any kind—the outside of the boxes is flat and even. This is a great secret in theatrical decoration; all ornament in relief is fatal to sound, it stops its progress and true course. The pit tier fits tight on to the floor; there is no walk underneath the lower tier at the back of the pit, as is very common in small houses; and, finally, the crowning effect of all is the ceiling: it is perfectly smooth and even, without any ornamentation in relief, and in form is a slight dome; it fits on to the top of the house like the top of a violin,—in fact, a theatre ought to be a sort of a violin, with the audience sitting inside it. The top of the house ought to follow the shape of the lower part exactly. Never was there such an egregious mistake as building a square top to a theatre that is round below, as at Covent Garden. The ceiling must fit on like the top of a pomatum pot, right away from just above the proscenium, which should flow with a smooth continuous curve into it. Architectural pillars and other excrescences by the stage boxes I look upon as perfect abominations; they are hideous, and spoil sound. Nothing is so beautiful as the smooth run of the boxes straight up to the proscenium frame, and nothing is so excellent for sound.

About intricate machinery I shall have something to say further on, when speaking of the stage. The pit floor at Covent Garden was made to be raised up to a level with the stage in case of promenade concerts, but this has never been done, as it was found easier to build a platform over the pit. The necessary framing and boarding in squares once made and numbered may be put at any time in thirty-six hours. The fire-proof construction of a theatre, as far as possible, will be best attained by proper arching; but the combination of iron with brick or stone, I can only look upon as cheap and bungling substitute for true arch construction. Ventilation will be best attained by strict attention to simplicity, elaborate systems invariably fail; plenty of holes near the centre of the ceiling, and a high pitched roof above, with large dormer windows, will secure the best, I am certain. About this high pitched roof I have something to say. Over the auditorium it is excellent for this very purpose of ventilation; secondly it gives you a large room above for scene

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painting, and too many places for this purpose you cannot have, as everyone knows who is acquainted with the production of a pantomime, or any elaborate piece within a given time. Over the stage a high pitched roof insures the best working of the drop scenes, for up in the top of the gable you place the barrel floor; being then in the centre, it secures as smooth an ascent and descent of the cloths as you can wish. How to light a theatre has of late years become a question of considerable importance, but I think without reason. Surely in an English theatre we have enough light. Do you not see one another sufficiently? Do ladies want any more light to expose their personal charms and costumes? On the side of the manager, I must say the gas bill is a fearful item of expenditure. You want to cut it down, not to increase it. I think we have sufficient light at present, but it might be better distributed, or made softer. The new system of lighting through a glass roof, as at the Theatre Lyrique, in Paris, consumes treble the quantity of gas. Moreover, a glass and iron roof is bad for sound: you will never make a violin of glass and iron, and this I think settles the question of sound. Nevertheless, a partial adoption of the system in the centre of the ceiling might be adopted; but the chimney above it must be made to move; so that in the day time, when necessary, the whole floor above may be used for painting purposes. Lamps in front of the boxes are intolerable from the heat they throw out. The foot lights have also received attention of late, but some light here is very necessary for stage effects, you cannot do away with it. By slanting down the stage a little, the foot-light arrangement, whatever it is, may be hidden, but in doing this care must be taken how the shadow falls on the cloths behind. The principle of a double pipe for green and white lights, as used at the Lyceum, is no novelty; it was introduced many years ago in the North of England. In fact I would warn architects against "flash" advertising gas firms, if you want your work well done. Get a good old-fashioned stage gas man who has some experience in such matters. Of course, what inventions may come up in the future we know not, but speaking strictly of the present I have seen nothing at all extraordinary, or likely to be of any great benefit. The gas pipes in a theatre should be visible in case of an escape, not hidden away in walls where no one can get at them; and the room of the meters should be a strongly arched vault for safety against explosion. There should be a large air shaft to ventilate this, and let away any escape of gas. In reference to the warming apparatus I have little to say, except that it must apply to both stage and auditorium. Architects in the present day know well the various systems; they have only to choose the safest and most economical.

Here let us rest awhile, and critically examine some few of the foreign and English theatres, at least just to observe some details of arrangement. But I must warn you, that I consider there is no theatre in Europe that can be considered a model in any way at all. I do not know any theatre that fulfils the wants of its locality, much more serve as a model for an English metropolitan or a provincial house. If a theatre is to be worth anything, it must be arranged from A to Z, *de novo* by the architect, and built for the especial site and for the purposes required by the locality. It is of no earthly use studying other theatres, it is so much time lost. The architect must use his own brains; and if he is gifted with plenty, he will build a good theatre; not without. The new Opera House at Paris seems to me to be very praiseworthy in respect to its conscientious arching throughout: there is none of that peculiar English sham, our construction of brick with iron; it is throughout *bonâ fide* arched construction. The basement seems to be arranged for certain especially local requirements, and thoroughly thought out; this, however, can be no guide to you, because you will have different requirements in every theatre.

The arrangement of the passages in the front of the house is certainly bad, but they are so disproportionately immense, in comparison with the number of spectators it is intended to hold, that much harm cannot arise. This huge building is only to seat 2000 persons. Just think of the area of Her Majesty's, which holds quite as many! However, the passages are so large, that this number cannot crowd very much. Still, the fault remains where it was; the staircases are arranged for grandeur of effect, not with the idea of use—not in accordance with the precepts I have laid down. But I may here once and for all say, that you will not find one single theatre in Europe where the passages are what they ought to be. It remains for an architect of the future to build a theatre well arranged in this respect. All theatres are sacrificed for grand halls; all the exit passages are made to lead into this hall. Darmstadt has stood godfather for half the modern theatres of Europe; Munich, Berlin, Moscow, and now Paris, are all godsons; only Paris is a giant, but decidedly deformed. In all these theatres the idea has been to collect the people into the hall. *Coup d'œil*, that has been the idea; reason, comfort, and safety sacrificed for outward show. I can say nothing about their passages and front arrangements but this—they are not worth the trouble of looking at. I will guarantee that if you pay attention to the simple rule of doubling the size of a passage wherever two meet, and of leading them out directly without turns, and without bringing them all into the front hall, you will produce a better house than any in Europe. For the arrangement of the dressing rooms, I think Munich is probably as good as any; but you can arrange this better by yourself, by your own brains than by studying Munich. If I have to call your attention to any theatre in Europe as worthy of study—not as a model at all, not as being of any value to you, but as a mental exercise—it is to the Colosseum at Rome. I think Mayence and Dresden curious exercises worthy of being seen. A theatre I never examined, but have been told its wardrobes were so complete, is Warsaw. The Victoria theatre, at Berlin, is a curiosity not without interest, a double theatre, one for winter and summer. In England we have some provincial theatres more or less well arranged; and some of the very old ones are often very practical, places that have been turned into theatres. Covent Garden, the largest of our most recent works, with the exception of those good points I have pointed out, is excessively faulty; that one staircase and large hall, with the narrow roadway for carriages, and no room for foot people, is very bad, and all the passages lead to this hall. Something very different might have been done on that site—two streets, and an entrance into Covent Garden. The whole thing was sacrificed to that portico—the evil spirit of grandeur. The old theatre in the Haymarket, cramped as that is for room, is emptied in half the time. A full night in Covent Garden, the whole place is blocked up after the performance is over. There is a curious idea here too, of a door out of the box lobbies into the gallery staircase. I suppose this is intended to let the people out in case of fire; but imagine the confusion, with the immense gallery tearing headlong down the stairs!

We come now to a very important point, the decoration of the interior. Great colouring and great decoration are not obtained by rule. If anyone would compare scientific with veritably artistic decoration, there is an excellent chance at South Kensington. One of the Courts at the side of the first hall has been elaborately decorated by one of our first "scientific"—remark "scientific"—decoratists. Anything more coldly monotonous and exact than the colouring you could not find. Well, just below this are two or three splendid cases of Japanese and Chinese wares, and their decoration, you know well, is not "scientific," but artistic. The contrast is really curious; the exquisite design, fancy, and colour, of these Japanese and Chinese wares is most marked when compared with the machine-like monotony of the scientific. How is it possible we can have decoration when it is not put under the direction of great artists? The decorator of the present day is a separate being from the painter; the decorator has become paperhanger. You cannot have decoration unless you do as was done in the middle ages—put it in the hands of a great painter. It is not absolutely necessary that he should execute all the work; but it is necessary that he should direct the whole. In the case of a theatre this would by no means be difficult, because the decoration must be of a kind to be easily renewed; the interiors so soon become dirty. Very elaborate highly finished paintings are out of place; in a few years they would be destroyed, and must be renewed. Therefore the decoration must be a simple effect of colour; superintended and directed by a thoroughly great colourist.

I have said already that all relief is inadmissable on account of its injurious effect upon sound; and I will further add, that everything in relief catches the dust, and soon makes the house look shabby; it is liable to be knocked off by the cloths hung over the boxes at night. Decoration in the middle ages was confided to a man like Giotto, and in the present day it must be directed and carried out under the guidance of any painter known as a great colourist.

Here I wish to call your attention to an excellent school of art in England. There is no necessity to go abroad, we have an excellent school whereon to found our modern work. In

Norfolk, there are numberless churches with beautiful painted roofs and screens—marvellous pieces of colouring, the very thing we want—they are English, and we want English decoration. Here then, in Norfolk, you will find a suggestive style, the traditions of which you must hand on. If you will will look at Brandon's 'Timber Roofs,' you will find a coloured plate of Knapton church—its roof. Nothing could be more suggestive for the decoration of a modern theatre; the yellow ground is the very best for gas light. There is about this plate, however, a dreadful exactness and evenness of tone that is never found in the original works. This evenness of tone in modern manufactures is wholly at variance with Eastern custom. The yellow of a Persian carpet is never for two inches alike, and this gives it that exquisitely pleasing character. Novelty, for its own sake, that is when sought for to make effect, every one knows has been the ruin of art in all ages, whether Classic, Gothic or Renaissance; the constant strain after novelty destroyed Gothic and brought Renaissance into Rococo. Novelty not arising out of use or wants is contemptible.

But at this moment our decorators are suffering from a huge nightmare of geometrical stiffness of form and cold arithmetical evenness of colour. The wisest remarks on decoration that I know are those by Mr. Ruskin, in the third chapter of the 'Two Paths,' a chapter that cannot be read too often. He plainly shows up the fallacy of supposing that it must always be geometrical and stiff; that geometrical decoration is very well in its place, but there is a higher form of decorative art; and the passage I shall quote describes the beauty of the landscape decoration of the Japanese most effectively, although not directly alluding to it. "Any of our people, bred on our fine modern principles, would have covered it with diaper, or with stripes or flourishes, or mosaic patterns. Not so Correggio—he paints a thick trellis of vine leaves, with oval openings and lovely children leaping through them into the room; and lovely children, depend upon it, are rather more desirable decorations than diaper." Mr. Burges has often and truly said, the human figure is rather more desirable than notches. The Japanese think landscape, trees and lovely birds are decidely better than geometry; they always give the right amount of work in the right place; they do not paint a miniature on a plate, but paint one of their home landscapes, with feeling, in one colour, grey-blue, on white plate; this is not a finished painting, that would be out of place, but a well executed sketch.

Having dealt so far with the interior, we proceed to consider the outside of the building. The theatre at Dresden is round, following the form of the inside; this is by no means a bad form, when you are not required to construct numerous saloons, and other rooms in front of the house; and on an open square it permits of any quantity of exit doors. Such a shape is out of the question in England, where the sites of theatres are usually cramped and in odd out-of-the-way positions. Here the architect must make the most of his ground, and work accordingly, However, I wish to protest most strongly against the air of grandeur that all architects think it necessary to give to a theatre, and which has raised in the public mind vulgar and fixed notions as to what the outside of a theatre must be. I wish particularly to protest against immense porticos and grand façades. In fact, I protest against grandeur generally—that sort of grandeur made up of arcades, continuous rows of arches, monotonous rows of windows, bound together by stringcourses and capitals. It is the sort of effect you see in the large warehouses of the City, recently built, and applies to Renaissance as well as Gothic. These buildings literally stink of money. Grandeur in a building is only another word for assumption, conceit, and "do the grand;" in other words, it is a lie. Now of lies and assumption there are quite enough inside the theatre, without parading the same to the public outside. But in what style is our theatre to be built? Greek is unsuited to our climate, and does not express the English mind; the same remark applies to Renaissance, and still further it applies to French or Italian Gothic. Therefore our theatre must be built in an English style, not eclectic, but one founded on the traditions handed down to us. What I should like to see an architect have the courage to do, is to build a theatre of English bricks, in the very simplest constructive manner, without any parade of grandeur or assumption at all. If you ask me what modern building it is to be like, I will tell you that plainly; it should be like the clergy houses attached to All Saints', Margaret street, by Mr. Butterfield, only still simpler, without the patterns of black bricks. These houses have a decidely English look; the windows are of a purely constructive form, put in just where they are wanted, without any attempt at façades and grandeur. It would be a pleasure for once to come down to honest simplicity, and to see a building without any capitals or carvings—an absence of ostentation for once. It is this pomp, showiness, and novelty hunting that is the curse of modern architecture, whether Gothic or Classic. We want to come down to the simplicity of the new buildings at Merton College, Oxford, or the shops in Worship Street, Finsbury. I would fifty times sooner have the monotony of Harley Street, than the vanity and pride of our new buildings in the City.

At last we come to the stage; but before I proceed, I shall suppose that the water apparatus and necessary fireman's arrangements, with tell-tale clocks, &c. have been duly provided for. The width of the proscenium should never exceed that at Covent Garden, if too wide it is very awkward for the actors; the height must be regulated by the gallery and back scene; the people at the back of the gallery should see the whole stage. By advancing the stage very far into the auditorium, you do much for sound, but it is much out of the manager's pocket; as hereby you lose so many rows of stalls, therefore a medium must be sought in this point. Of the footlights I have already spoken, we will sink the stage a little, and hide them from the eyes of the public. Here, too, we must not omit the orchestra; its floor should be sunk deeper than is usual, so as to hide the violin scraping, which rather spoils the illusion. The stage is a picture which the audience look at through a frame. The proscenium, then, must be treated strictly as a frame; and the drop scene, being so long before the audience, should be a picture excellent in every way, and pleasing to the eye. The construction of the stage hardly fails within the province of the architect, it must always remain the work of the master stage carpenter. Touching foreign stages I shall remark, that they are in no way better than our own, if anything inferior. In France no changes of scene are made without dropping the curtain. In England the quickness with which we change a scene before the public is wonderful, and a great credit to our master carpenters. In Germany the changes are perfectly ludicrous; the wings often, as at Munich, move by counterweights from a central barrel on the mezzanine floor; the change is very steady, very slow, and very German. You never can work by machinery as quickly as by men's arms, particularly Englishmen's. With French stage carpenters there is such a noise, that I do not think you could safely allow them to make a change before the public. Machinery of all sorts has been tried on the stage, and invariably failed, more especially in England with our pantomimes. Nothing but men to each wing and in the flies can do the work as it ought to be done. All practical stage managers prefer as little machinery as possible; nothing works like the old barrel and counterweight. It is only a favourite scheme with all novices to imagine some complicated system of machinery. Old stagers know what it means at once. The foreign principle even of working the wings on ladders running on a train on the mezzanine below, is wholly useless in England. We find nothing works so quickly as the old fashioned wing, with a wheel in front, each wing managed by a carpenter. It is very easy to talk about deep stages of 100 feet and upwards, but you must remember the number of extra men you require on each side of the house for every extra 10 feet, and the quantity of supernumeraries to fill up the stage; all these have to be paid. With a clever scenic artist, 60 feet is deep enough for all purposes. On the other hand, great width behind the proscenium is of importance; you cannot have too much room at the sides of a stage. In England I think we have not fairly considered the German question of a flat stage, instead of one on the incline. It is a question worthy of more attention than has been given to it; it has become very general abroad. The stage of the Victoria Theatre at Berlin is flat. In London for the last three years it has been much more general than formerly to have built up or set scenes. The Lyceum is now constructed purposely for these, but it cannot be considered successful when carried to that extent. If a new piece had to be brought out suddenly, or a change of performance take place, it could not be done; there is so much labour involved, and a pantomime is out of the question. But with all these technicalities the architect has little to do, he must seek a good practical stage carpenter, and leave the stage building to him. There are only one or two points; I think the flies might be higher up than they are, and with a slight alteration of the batten lights we might get rid of sky borders; those pieces of canvas very unlike sky. Of course I presume you will build high enough to allow the cloths to go up straight, without being caught up in the centre by a batten, as at Covent Garden; a plan that entails more machinery, and double expense in rope. The woodwork of the stage floor should be so made that it could be taken up and cleared away at any time, portable in fact; you never know how you may want to cut your stage about. Great depth below, and clear width without wall, is very necessary; sinking scenes the full width of the stage are common in fairy pieces. The mezzanine floor should be at least 8 feet high, and as clear as it can be made. The various rooms required for the different departments will differ in every theatre, and the architect must have a clear understanding upon this and all other details with the manager beforehand. Near the orchestra you want a waiting room for the musicians, with cupboards for their instruments and coats, lavatories and other conveniences; the music library should not be far off. One painting room we have already, over the auditorium ceiling, but we want another at the back of the stage, arranged as at Covent Garden, where the artist can paint against the wall upright; contiguous to this must be the carpenter's shops. Then the property and armoury rooms must be near the stage, and a very well ventilated property shop, for the making of green leaves and other necessaries is a most unhealthy employment. The dressing rooms for men and women should be kept apart, on opposite sides of the house if possible, with tailors' and dressmakers' shops and wardrobes just above them, and fitted with lifts to send costumes up and down. Supernumeraries and soldiers' dressing rooms are also required. A large magazine near the stage, to keep the stock scene cloths and wings, properly fitted with racks and grooves, to stow them all away in good order; this should be so placed as regards the stage, that the cloths may be taken straight in without any corners to pass. But above all things I must remark that your stage and passages must be free from all wind and cold air. Singers' throats must not be lost sight of; plenty of swinging doors, and proper waiting or green rooms for men and women, are of the utmost importance; for no one ought to be on the stage that is not immediately concerned in the act. Proper apartments for firemen, hall porter and housekeeper; kitchen and cellars; rooms for the manager, secretary, treasurer, chorus and solo practice; and water closets, &c. throughout the house; and I think we have pretty well run through the requirements. I have now only to add that, imperfect as my endeavours are to enlighten you on the subject of theatres, they are, at least, founded on experience, and as such I trust you will accept them, with all due consideration for shortcomings.

Mr. T. Hayter Lewis, said, that he thought the thanks of the Institute were due to the author of a paper like this, as it must have cost him much time and labour in its preparation, and he had great pleasure in moving the vote accordingly; but he was under some little difficulty with respect to it, as he differed very much from Mr. Taylor in many points touched upon. Mr. Taylor had run through all the requirements of a theatre, and to some extent he agreed with him. He went with him entirely as to the decorations; he would even go a little further, and say, he thought that not only the decoration should be directed by a thorough artist, but that the architect himself should be so qualified as to be that artist, and so to finish his own work. He did not think that any person, however gifted, could so thoroughly enter into the feelings of the architect as properly to finish the work which he had designed. With respect to the accesses, no doubt Mr. Taylor was correct in saying they must have as numerous accesses, or rather egresses, as they could, and he supposed they would all try to do that, so far as space would allow. He thought Mr. Taylor had too much put aside the requirements of architectural skill in designing the inside as well as the exterior. He had argued that there was no poetry in these things, but simply that theatres were matter-of-fact places for hearing and seeing. For his own part, he thought that of all buildings a theatre was the one in which the fancy of the architect could be most freely indulged. It was adapted for scenic decoration; it was a place of pleasure; and it seemed to him the architect ought to exercise his utmost artistic skill upon it. He did not say that he could work upon it with the same deep and earnest feeling with which he would be actuated in designing a sacred edifice, but it seemed to him to afford scope for the exercise of the greatest artistic power. With regard to acoustics, Mr. Taylor had laid it down as a law that the shape of the auditorium should resemble, both at the top and bottom, that of a violin, that was to say, that the form which gave the best sound externally, when acted upon from the outside, as a violin, would be the best also where the auditory and the sound-producing force were inside, as in a theatre. That seemed to him as opposite a conclusion as could be. A theatre, with its deep recesses and partitions, was as opposed to the theory of acoustics as one could conceive. He remembered consulting one of our most eminent Scottish philosophers respecting the plan for a church; the answer was, that in his opinion the principle he (Mr. Lewis) had adopted would most probably answer, but, he added, that he had studied acoustics probably as much as any man, and the conclusion he had arrived at was that, in applying theory to actual practice he knew nothing about them, and he believed nobody else knew more. When such an opinion was given, with the true modesty of knowledge, it behoved us all to be careful in laying down a law too strongly. With respect to construction, he did not quite understand Mr. Taylor as to arching. He agreed that cast iron and brick arches were not fire-proof, and he believed not so much so as good solid oak beams and thick plastering; but he did not understand how brick arches and solid piers could be applied to the ceiling and supports of the boxes. [Mr. Taylor observed that his observations applied to the passages. The arches of the passages were often constructed bearing on iron girders.] It depended very much on the construction of the girders; but brick arches on solid piers were, no doubt, a great deal better than iron girder construction. There was one other point to which he would refer. He was lately called upon to design a theatre very rapidly. He had seen most of the theatres mentioned by Mr. Taylor, and also those in Italy; and if he had had time he should have looked at their plans to see if he could improve by them upon his own notions, so as to be able to make a perfect theatre. It seemed, however, that it was Mr. Taylor's opinion that no theatre was known which was not badly designed, and it was, therefore, to some extent, consolatory to know that one need not trouble oneself about anything already done, but that by exercising common sense only, we could, from the depths of one's own consciousness (to use a German phrase), work up the perfect design required. As to the exterior of these buildings, he was sorry to differ entirely from Mr. Taylor, for, if he understood him right, he would have the exterior of a theatre like Mr. Butterfield's houses in Margaret Street, only without even their slight ornamentation. In fact, the ideal seemed to be as near as possible that of a Quaker's meeting-house. He had a strong objection to that, in an artistic point of view. Mr. Butterfield's elevation seemed, no doubt, unexceptionable for the particular purpose, and the plainness of a Friends' meeting-house corresponded well enough with the severity of their worship; but there would be an end to all expression in architecture if the same style of elevation were properly used for two such opposite purposes as those of a meeting house and a theatre. He objected, no doubt with reason, to great porticoes and such things, which were put up merely for artistic decoration, without use, but that a theatre should have no exterior decoration he could not agree. The various hints, however, as to the actual working of a theatre, coming from a gentleman of Mr. Taylor's practical knowledge, must be valuable.

Mr. PAnson, remarked that he had lately visited one of the large theatres in Paris, built on the *quai* side, finished within the last few years. Last week he visited the Théâtre du Châtelet, and had an opportunity of seeing the effects of lighting from a glass roof, and he could quite understand that such a method of lighting involved a very large consumption of gas, but he could not say the effect was to his mind satisfactory. It was wanting in the brilliancy which English theatres possessed, and which the other theatres in Paris, not so lighted, exhibited. He thought, as far as he could judge, that it was not a happy introduction, and took away much of the artistic effect which was produced by a solid ceiling, and he thought it was not conducive to the spread of sound. He had been surprised at the statement made by Mr. Taylor that the scenes in the French theatres could not be shifted without dropping the curtain; for he had himself seen it done, and in this respect, perhaps, they had taken a lesson from us. One thing which, in his opinion, detracted very much from the comfort of theatres was the modern practice in France and Germany of adding balcons in front of the stage boxes, which overshadowed the pit and rendered it very dull and disagreeable. In fact, the pit seemed at the present day to be dwindling to nothing, its space being occupied by orchestra stalls, and arm-chairs. In the Théâtre du Châtelet the line of boxes ran up like a large picture frame to the proscenium; with an unbroken line round the auditorium of the theatre.

Mr. Taylor said, as regarded the shape of a theatre being like that of a violin, the sound of a violin was produced from its board—the top and bottom joined by the sides—and if that produced the best sound, internally the sound would be the same. It was exactly the same principle as in a whispering gallery. It was the peculiar form which carried the sound round, and he was quite certain that was the form of the best theatres in Europe, and the wood being seasoned almost to rottenness, it sounded live an old violin. With regard to the balcon principle, he considered it was bad in the French theatres. He regarded the Mayence theatre as answering the purposes for which it was required, as the best building of the kind he had seen. It was an admirable theatre inside, and was spared the unsightliness of the balcons stuck on the front of the boxes. With regard to the French scene shifters, he believed they had somewhat improved in their practice, but they were quite incapable of managing pantomimic scenes in the way in which it was done in this country.

Mr. W. Burges remarked, that the theatre at Padua was in the form of the old Roman theatres, the pit being quite free, and surrounded by four or five concentric rows of seats, following the course of the two tiers of boxes above. It was certainly one of the most beautifully decorated he had ever seen. In the 'Dresses and Decorations,' by Mr. Shaw, there was a reduced copy of a print of a Mediæval theatre, from the 1496 'Terence,' published at Strasburg. In the centre of the space occupied by the building two concentric galleries rose one above another. They appeared to be attached to a circular pillar in the middle, which probably did duty for a staircase. Three little gabled erections at the foot of this central staircase or pillar did duty for the scene, or perhaps for the green room, while the performance took place on the vacant part of the floor. The whole design was doubtless due to a misunderstanding of Vitruvius.

THE MANAGEMENT OF TOWNS.

III.—*The City of London.*

The particulars that have been given of the duties performed by the inspectors appointed by the City Sewers Commission will conduce to the proper understanding of the system which it is the duty of the Engineer and Surveyor to direct. The following classified account of the matters that are considered to be in his department is probably as nearly complete as the nature of his office will allow of our giving in detail; it being understood that the whole of the matters connected with property and works of every kind that belong to the commission come under his supervision, and that from the progress of science operating in the development of new matter, which is from time to time added to the jurisdiction of the commission, his duties are continually upon the increase. These duties are highly onerous, and involve an amount of responsibility which can only be fully understood by those who are engaged in labours of a similar kind. There are, indeed, hardly any positions either of a public or private nature that can be filled by the architect or engineer in which the mass of detail requiring to be dealt with is so vast and so varied, and in which mature judgment, habits of business, and personal attention are so necessary as in an office of this kind. In the case of the City of London these remarks, of course, apply in a very high degree, the annual expenditure of the Sewers Commissioners for works under the engineer being about £95,000.

The engineer and surveyor attends, as a rule, every court and committee, and advises them upon questions that arise connected with his department. He reports annually upon the works executed by the commission, and upon special occasions he examines into and reports upon the working of any part of the system actually in operation, and upon any proposed modification of it. During the last few years it has been found necessary to reconsider the whole question of pavements, cleansing of streets, gas lighting, water supply, street traffic, flushing and ventilation of sewers, with the possibility of utilising the sewage, consumption of smoke, construction and regulation of cow-houses and slaughter-houses, cemetery management, and other questions similar in kind. This has necessitated the acquisition and classification of data from many sources, and the preservation, in an accessible form, of all records of works done under the commission, with the result of examination into their state at frequent intervals. Experiments are from time to time made, and statistics compiled, both with immediate reference to the necessity of reporting and with a view to possible requirements. In the case of railways and other schemes, when the power of interfering with streets is sought, special reports are compiled, and for many past sessions of parliament this duty has involved a very considerable amount of labour, which may still increase. When the commission decides upon appearing in committee upon any of these bills, the engineer prepares evidence on their behalf. He holds the necessary interviews and conducts the correspondence with persons directly interested in the business of his department, and with the rather large class of persons who either upon public grounds or as promoters of projects desire to communicate with him as the officer of the commission. He projects improvements in the lines of streets, and negotiates the purchase of the property required, makes the necessary plans and valuations for this purpose and for letting the surplus ground, and the ultimate sale of the ground rents when improvements have been effected.

As the engineer is responsible to the commission for the whole of the matters within his department, including the proper performance of works under the subordinate officers, who must appeal to him in cases of difficulty, and report, he must be in constant communication with the inspectors, clerks of works, and contractors, and at hand to advise and direct them in all cases requiring professional knowledge, and as to times and modes of performance of works. As to the works themselves, the following summary of those which are of most importance will present at one view the chief matters which belong to the ordinary routine of town management. The preparation of plans, specifications, and estimates for new sewers and reparations, and of specifications and schedules for works to paving, and for lamps, urinals, scavenging and watering of streets, gas-lighting, and for minor purposes, the superintending of the execution of these works, and measuring and making up the accounts. This involves the keeping of weekly vouchers, and notes, and memoranda, from which the records of works are compiled, and by means of which the plans of sewers and other works can be corrected, so that they represent at all times the actual condition of the matters to which they relate. The engineer has under his charge a stone-yard, and he regulates the supply of materials, and their delivery to the contractors for works, all orders for these purposes coming from him. As regards house property, he takes plans, and lays down the lines of private drains, estimating the cost of those portions which are beneath the public way, and keeping records for future reference; makes out licences for private vaults; directs the execution of compulsory works upon premises where the owners have neglected to comply with the orders of the court, and is responsible for the economical management of such works. Every application of a private owner for a projection for shop-front or other privilege over the public way, is referred to him for his report before it is granted, and, if necessary, he attends a committee of the court to view the premises. Rules for the construction of slaughter-houses, cow-houses, and common lodging-houses occupy his attention (but their periodical visitation for the prevention of nuisances is in the department of the medical officer); and as the Sewers Commission is the Burial Board for the City, he acts a stheir surveyor in all matters connected with the cemetery.

With the view of further illustrating the system by means of which the state of the works in charge of the City Sewers Commission is periodically brought before them by their engineer, the report, made to the court upon works executed during the year 1864, is here given. Although some portions are of local interest only, they will assist in showing the method of classification adopted, and may also give, incidentally, some useful hints upon points that have not been treated on in the course of the preceding remarks:—

Report of the Surveyor to the Sewers Commission for the City of London.

Sewers.—The total length of new sewers built was 1597 feet, of which 831 feet were reconstructed upon the line of old sewers.

* Continued from page 35.

The total number of premises drained during the year 1864 was 230
The approximate number of premises known to be drained at the end of the year 1864 was 13,548
The total number of houses, of which some record is now possessed as to their being drained, is about 13,778
The approximate number of premises about the drainage of which nothing is known, and which have hitherto been set down as undrained, is about 2,223

During the year 141 plans, which show the drainage of 230 houses, were made; nearly one half of the plans were for the drainage of new premises.

Improvements.—Improvements were completed by setting back the frontages of Nos. 4, 6, and 8, St. Dunstan's hill; No. 12, Little Knight Rider-street; Nos. 47, 48, 49, and 50, St. Mary-axe; Nos. 6, 7, 8, and 9, Cooper's-row; No. 35, Bishopsgate-street Without; No. 28, St. Mary-at-Hill; and No. 60, Gracechurch-street. The eastern end of Colchester-street was widened, and the archway in that street next to Cooper's-row altogether removed; the widening of Angel-street was completed by the removal of the house No. 15, St. Martin's-le-Grand, and the angle of the property at the end of Lime-street, in Fenchurch-street (west side) set back.

Works are in hand, by which the whole of the church-yard of St. Lawrence Jewry will be levelled, and the surface be added to the public way; thus increasing the footway from 6 ft. 6 in. to 35 feet in width; also for setting back a portion of the church-yard of St. Olave, Silver-street, by which the street at that spot will be widened from 17 feet to 25 feet.

Arrangements have been completed for setting back the frontages of Nos. 67 to 70 inclusive, in Newgate-street, and the houses Nos. 71, 72, and 78, have also been purchased to continue the widening of that street; three houses, therefore, will only remain to be taken down between Bath-street and St. Martin's-le-grand, and those three are scheduled by the Government for the acquisition of a site for the extension of the General Post Office. The completion of the widening of the eastern end of this important thoroughfare may therefore be shortly expected.

Arrangements also have been made for canting off the angle of No. 54, Fore-street, and of Nos. 1, and 8, New Basinghall-street; for setting back the frontages of Nos. 65, 66, 67, and 68, St. Mary-axe, and Nos. 117 and 118, Leadenhall-street; for improving the junction of Threadneedle-street with Bishopsgate-street Within, on its northern side; for widening the narrow part of Clement's-court, Milk-street; improving the line of Three Cranes-lane; setting back the frontages of No. 71, Bishopsgate-street Within, and Nos. 36 to 39, Bishopsgate-street Without; also for widening Camomile-street at its western end, and setting back the adjoining frontages of Nos. 60, 61, and 62, Bishopsgate-street Within; rectifying the line of frontage of the houses from Nos. 22 to 26 inclusive, on the west side of Tokenhouse-yard, and canting the corner of Cloak-lane and College-hill.

Negociations are pending for a small improvement at the western end of Throgmorton-street; for taking down the external aisle of the church of Allhallows, Upper Thames-street, with the view of continuing the widening of that throughfare; for slightly widening Bishopsgate-street Within and Leadenhall-street, at the junction of those streets where the foot traffic is so excessive and condensed; for rectifying the line of frontage between Nos. 64 and 68, Old Broad-street, for improvements in the lines of Hart-street, Monkwell-street, and Fell-street; and of King's Head-court, Shoe-lane.

Early in the year the commission resolved to open a carriage-way through Blue-coat-buildings, from Little Britain into King Edward-street, with the view of relieving the narrow part of Little Britain and forming a direct line of carriage-way from Newgate-street to Smithfield. The premises No. 70, Little Britain, and No. 18, Bull-and-Mouth-street, have already been purchased for this purpose, and the purchase of the remainder of the property is now being negociated. The commission also approved of a plan for the formation of a circus at the junction of Ludgate-hill, Fleet-street, New Bridge-street, and Farringdon-street; the eastern half of which is ordered to be carried out forthwith, and negotiations for which are pending.

Arrangements are also pending for an improvement in the street lines of the property facing the lower end of Tower-hill and Trinity-square, by which the eastern entry to Barking-alley will be widened and Barking Church-passage be made of an uniform width; also for a slight improvement upon the eastern side of the Old Jewry, and an extension of the widening of Threadneedle-street, east of the Bank of London.

A beneficial arrangement was entered into with the Charing Cross Railway Company, by which Bush-lane is to be diverted and straightened at its southern end, and Dowgate-hill made (with the exception of a small portion) not less than 40 feet in width. A considerable improvement arranged three years since with this company, by which Upper Thames-street, for a length of 220 feet, was to be widened from 20 feet to 37 feet, was during the year carried into effect.

Surface Cleansing and removing Dust from Premises—The contracts for scavenging and dusting were let from Midsummer 1864 to Midsummer 1865 for £7839, which was £430 less than the letting of the previous year; the total of the contracts were also lower than it has been for some years, as will be seen by the following table:

For the year ending Midsummer	1862,	£8252.
,, ,,	1863	8415.
,, ,,	1864	8260.
,, ,,	1865	7830.

Upon the whole the work was well performed during the year.

Street Surface Watering.—The contracts were let at £1296, being £147 less than the previous letting. No complaints of importance were made of the performance of the work during the year. The cost of surface watering also has been annually decreasing for some years, although for some years past there has been annually an increase in the area watered. This will be seen by the following table:

For the year ending Midsummer	1860,	£1244.
,, ,,	1861	1263.
,, ,,	1862	1327.
,, ,,	1863	1365.
,, ,,	1864	1443.
,, ,,	1865	1296.

It has been the custom to discontinue the watering at Michaelmas-day, and the contracts have been framed accordingly. The exceptional dryness of the autumn of 1864 rendered the continuance of the watering needful after that day, and special arrangements had to be made with the contractors to carry this out; it may be well in future contracts to provide against this.

Pavements.—The carriage-ways paved with new stone, were those of Moorgate-street, and Watling-street from Bread-street to St. Paul's churchyard. The carriage-ways of the Minories, Bishopsgate-street Within, King William-street from the statue to Lombard-street, the western half of Cornhill, and the southern half of Gracechurch-street were relaid; large quantities of new stone being required in each case, The footways of Ludgate-hill and street were repaved with new York. The Granitic Breccia laid in the southern footway in Long-lane in 1855 was removed; being thoroughly worn out. In addition to these works, an unusually large amount of repair was executed generally throughout the City; some of the work of 1863 having been postponed until 1864 on account of the large occupation of the public ways by the gas and water companies during that year, which precluded the commission from executing their works of paving advantageously,—and also owing to the commission resolving to postpone some extensive relays and renewals.

Urinals.—One was erected in the carriage-way of Crutched-friars capable of accommodating six persons. One in Alderman's-walk to accommodate three persons. One erected some years ago in Mumford-court, Milk-street, was removed. The number of these constructions is now very considerable. Their maintenance involves annually the expenditure of a large sum of money, of which the water supply is the most important item (see Water Supply); a list of those now under charge of the commission is given. (The list appears in the report.)

Public Lamp Lighting.—Tenders for supplying the City for the year commencing 1st February, 1865, were received in the month of December, 1864. Specifications of conditions were prepared as usual, but the companies declined to tender upon them, and they tendered subject to the conditions of the Metropolitan Gas Act only.

The tenders sent in were as follows:

Name of Company tendering.	Description of Burner.	At per Lamp per Annum.	Lighting, Extinguishing, and Repairing Lanterns at per Lamp per Annum	Transferring services at per Lamp.	Total per Lamp (not including transfer of services).
North District.		£ s. d.	£ s. d.	£ s. d.	£ s. d.
Great Central Gas Consumers' Co.	3 ft.	2 17 6	0 15 0	0 10 0	3 12 6
,, ,,	5 ft.	4 13 6	0 15 0	0 10 0	5 8 6
Chartered Gas Company ...	2 ft.	1 18 0	0 15 0	...	2 13 0
,, ,,	2½ ft.	2 9 6	0 15 0	...	3 4 6
,, ,,	3 ft.	2 18 6	0 15 0	...	3 13 6
,, ,,	4 ft.	3 16 0	0 15 0	...	4 11 0
,, ,,	5 ft.	4 14 6	0 15 0	...	5 9 6
South District.					
Great Central Gas Consumers' Co.	3 ft.	2 17 6	0 15 0	...	3 12 6
,, ,,	5 ft.	4 13 6	0 15 0	...	5 8 6
City Gas Company ...	3 ft.	3 14 0		0 10 0	3 14 0
,, ,,	5 ft.	5 9 6		0 10 0	5 9 6

The tender of the Great Central Gas Company was accepted for the South district; that of the Chartered for the North. Their charges were exactly the same as those for the previous year (1864).

The cost of public lighting has largely increased during recent years, which will be seen from the following table, constructed from the treasurer's accounts.

Moneys paid from the Chamber of London for Gas Lighting during the following years.

For 1 year ending 29 September,	1854	... ...	£8,738 17	4
„ 1 „	1855	... ...	8,726 17	0
„ 1 „	1856	... ...	8,833 12	7
„ 1 „	1857	... ...	11,792 7	1
„ 1 „	1858	... ...	11,819 1	0
„ 1 „	1859	... ...	11,909 13	1
„ 1 „	1860	... ...	12,841 14	8
„ 1 „	1861	... ...	12,855 11	10
„ 1 „	1862	... ...	9,947 5	1
„ 1 „	1863	... ...	15,797 2	0
„ 1 „	1864	... ...	14,512 19	0

This table will only show generally the increase which has taken place, as it sometimes happens that in one year portions of more than four quarters gas accounts are paid, and in another year less.

The question of gas supply, either in relation to its price, illuminating power, purity, or in other respects, largely occupied the attention both of the commission and its special Gas Committee; indeed the commission scarcely ever met during the year without the question of gas supply being introduced. The general results of the experiments which have been made by your officers during the last three years, and the investigations of the Gas Committee, form the subject of reports which are now being completed.

When deficiency of light was complained of at the public lamps, the statement almost unvaryingly made by the gas companies was that it was owing to the carburetting system. Looking at all the circumstances attending the gas supply to the City, the commission deemed it desirable to remove all grounds for this allegation, and have directed the carburettors to be removed. All the circumstances bearing upon the subject have been fully dealt with by your Medical Officer and myself, in a recent report to the special gas committee, and it need not therefore be dilated upon here.

Water Supply.—The amount paid by the commission during the year for water was as follows:

For supply to Urinals	... ...	£388	8	4
For flushing Sewers	... ...	21	18	0
For washing Courts	... ...	112	17	0
For Drinking Fountains	... ...	30	4	4

This does not include the money paid indirectly by the commissioners for street surface watering.

The supply to the public urinals is the most serious item, and is one which is yearly increasing. It should be known that up to the year 1856, the water companies charged only a sum of five shillings per annum for each compartment, which was a mere nominal amount; but since that date the supply has been given at the minimum rate charged to large consumers, and hence the large annual outlay required from the commission.

Dangerous Structures.—The business transacted by the commission under the Metropolitan Buildings Act may be gathered from the following summary of cases prepared by your principal clerk:

Number of structures reported upon by the surveyors appointed by the commission	66
Number of cases heard before the magistrates	21
Number of buildings shored up during the year	9
Number of cases certified by the surveyors as being completed	20

The number of dangerous structures reported upon by the District Surveyor during the year, was less than in any year since the business relating to them has been conducted by the commission; the number of cases heard before the magistrates was, however, proportionably much greater than usual; indeed, there has been no year upon which so large a proportion of the cases has been heard before the magistrates.

Drinking Fountains.—No additional fountains have been erected; there are but five within the jurisdiction of the commission.

House Inspection and Removal of Nuisances.—From the return prepared by your principal clerk, it appears that, during the year, 11,387 inspections of houses were made by the inspectors under the direction of your Medical Officer of Health, and consequent upon their reports the following notices were issued:

For works of drainage	16
For preventing the issue of waste water upon the surface of pavements...	51
For lime-whiting and cleansing the interior of the premises ...	1358
Total	1425

In the spring the senior inspector of pavements was superannuated, and at that period a change was made in the arrangements respecting house visitation and the suppression of nuisances. Four inspectors of pavements were only retained (there had been five for some time previously), and the area of the City was equitably distributed among them; they retained all their former duties, excepting that of house inspection for purely sanitary purposes. An additional sanitary inspector was then appointed, and there are now therefore two, who under the direction of the medical officer of health, perform the house inspection, give the requisite notices, and superintend the works requisite for the suppression of nuisances. Under this system a large increase has been made in the number of inspections of the houses of the poorer classes over that of recent years, and the notices for the suppression of nuisances have been increased likewise. The lodging houses are supervised by an officer specially appointed for that object.

Slaughter-houses.—The number of slaughter-houses existing in the City is now 63, being 3 more than at the end of 1863.

Cow-houses.—The number of cow-houses is now 19, being one less than at the end of 1863.

Lodging-houses.—The number of houses upon the register is 128, being a decrease of 7 upon the registration of the previous year.

City Cemetery.—The number of interments in the cemetery during the year 1864 was 5892, being 267 less than in the previous year. The revenue derivable from the cemetery was, however, much larger than it was in the previous year, and there is every reason to believe that it will continue to augment annually.

Miscellaneous.—At the commencement of the year plans and bills had been deposited in parliament for twenty-three projects affecting the City, of which nineteen were for railways, and four for works of a public character; the investigation of these projects was almost the first work of the year. Of these bills eight only passed through the legislature and became Acts, viz.—the Metropolitan Railway (Extension to Trinity-square, Tower-hill); the Metropolitan Districts Railway; the Great Eastern; the London and Blackwall Railway Extension; the London, Chatham, and Dover; the Charing-cross Railway (City Terminus) additional powers; the Holborn Valley Improvement; and the Pneumatic Dispatch Company. The supervision of the meat markets was stringent; yet a case appears to be made out for even increased stringency, inasmuch as about 102 tons of meat was seized by the inspectors, and condemned as unfit for human food. The senders and sellers of meat were, in many cases, successfully prosecuted and fined; nine were imprisoned. The works of the Metropolitan Railway extension to Finsbury, the Charing-cross, the London, Chatham, and Dover, and the North London railways, were rapidly carried on in the City during the year. With all these companies the commission made arrangements for widening and improving important public ways before their Acts were passed; these improvements are now being carried into effect, and the City will be largely benefited thereby. The Pneumatic Dispatch Company commenced laying a tube of large dimensions in the City; it is their intention to lay it from Holborn to the General Post Office.

In another paper we purpose giving some further details of the system now in use for effecting various kinds of work that are carried on by the City authorities.

(To be continued.)

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

At the meeting of the Institute of British Architects, held on the 6th ult., a paper was read by Mr. J. P. Seddon on "*St. Nicholas Church, Great Yarmouth, Norfolk.*" After an introductory history of the church, Mr. Seddon remarked that in the early part of the thirteenth century the church that existed previously, and which had been erected by Bishop Lozinga, was taken down, excepting a portion of the tower, and another and a larger church was constructed on the same site, the centre tower being alone preserved. Of this tower there now only remain the core of the piers, a portion of their base mouldings, and the two lower stages, the upper of which is surrounded by a Norman arcade. In 1847 some excavations were made to ascertain if any part of the destroyed church remained, and several portions were then brought to light.

The next form of the church was that of a complete cross church of very early Pointed or late Transitional work, around the Norman tower. This church was erected about 1190. It had a nave of eight bays, with lean-to aisles. The string-courses which received the plates of the roofs of these aisles and the corbelled eaves-courses of the wall above them are now visible from within in the present aisles. Of the transepts, and the chancel and its aisles, of this church, only the responds of (probably) arcades of two bays eastward of the tower exist. Before this church was completed, it was again enlarged in 1251, the aisles of the nave being re-constructed, with a clear width of 39 feet each, in the then more developed First Pointed style. The next enlargement was the extension, eastwards, of the chancel, with aisles equal in width to those of the nave, in the Geometrical Middle-Pointed period. The transepts were also raised to the same height as that of the aisles, and a vaulted porch was also added on the south side of the nave. The church thus assumed the character of a noble structure, cruciform on plan, with a centre tower, surmounted by a spire, covered with lead, the whole 186 feet high from the ground. The church was also rich in furniture and internal accessories. An elaborate rood screen was erected by Roger de Haddiscoe. In the north aisle of the chancel there was "a fair pair of organs." In and about the church were nineteen chapels, and in the aisles of the chancel "miracle plays" were acted. In 1330 an entirely new building, 167 feet by 47 feet, was commenced at the west end of the nave, called the Bachelor's Aisle, but this was subsequently abandoned, owing to the ravages of the plague in 1348. Other works were erected about the year 1400 and (subsequently, including, probably, the present waggon-shaped roofs, the windows of the aisles of the nave, with their meagre Third Pointed tracery, the reredos at the east end of the chancel, the parvise over the south porch, &c.

After the Reformation, St. Nicholas' Church shared the fate of so many other churches—viz., that of being rifled and despoiled, and in being suffered to fall into a deplorable state of neglect and decay. This state of desecration continued till as recently as 1845, when, under the auspices of the Rev. H. Mackenzie, then the incumbent, and since sub-dean of Lincoln, considerable restorations were effected, under the superintendence of Mr. J. H. Hakewill. In 1862 another committee was formed, and still greater improvements were set on foot. Mr. Seddon then proceeded to a more detailed description of the condition of the church when he undertook the restoration. The plaster was stripped from the walls on the side of the tower, above the large arches leading from the chancel aisles to the transepts, and these were found to be seriously fractured. The piers of the chancel arcade were found to be much decayed, and the whole area of the chancel near the tower was honeycombed with vaults. These were filled solid, and concrete, two feet thick, was put over the western part of the chancel floor, and round the damaged piers. The south pier was rebuilt, and the north pier made good. The walls were carefully repaired with strong bond stones, and the part above the roof re-cased. New solid gable walls, with stone copings and weatherings, were built to receive the roofs of the chancel and transepts, and the angle quoins re-constructed. The old iron ties and bars were removed, the holes filled up, and new ties, pinned together at the angles, and tailing two feet into the walls, were inserted in new stone strings; other ties were also inserted; the whole casing was built in cement, and the walls grouted with liquid cement. The flint-work was faced with split flints; the Ashlar of the First Pointed work was rebuilt, stone by stone, and the north and south fronts of the tower were faced with freestone, in random-coursed work; the cornice and parapet were taken down and replaced with new work, with turrets at the angles.

Mr. Seddon then remarked on the two magnificent windows at the west end of the nave aisles, the southern resembling in its external arrangement that in the west front of Llandaff Cathedral, while that on the north side is very similar to the same window in its internal arrangement. In conclusion, he said that the Third Pointed work of the church did not call for a more detailed description than that he had already given of it.

A discussion followed the reading of this paper.

ON THE MUNICIPAL ORGANISATION OF PARIS, WITH REGARD TO PUBLIC WORKS.*

By George R. Burnell, Esq., F.G.S.

It seems that, at the present day, the results that have been obtained by the organisation of the service of public works in the neighbouring capital, have dazzled the public to such an extent, that it would not be surprising were an attempt made to introduce some imitation of that system into our own country. Paris has been transformed with almost fairy-like rapidity; it has been improved in its hygienic and its general character; it has become essentially the city of pleasure, and the abode of the man of intellect; public buildings of a fine monumental character have arisen on every side; and at the same time the service of the city, in so far as regard the daily wants of life, has been largely and well cared for. Railway stations have been opened, markets laid out; mairies, public schools, churches, hospitals built; and even theatres and places of public amusement have been founded with a degree of luxury of which we in England have no conception. The results that have hitherto attended the Imperial Government of France have, indeed, been such as to cause both surprise and admiration; but I think that they are the results of a system that would prove eminently a failure if applied in our own country; and, as I flatter myself I know something of the innermost details of the administration of that country, I have thought that it might afford you some instruction were I to give you an account of the municipal organisation of Paris. There is much to be learnt from what is passing amongst our neighbours, no doubt; there is also much to be avoided. It should be our duty to learn all that they do that is worthy of imitation, in order to place the administration of our capital upon as sound a basis as possible, after allowing for the different circumstances of the social organisation of the two countries.

The first things that strikes the inquirer in the municipal organisation of Paris, are—first, that the capital and two of the great cities of France constitute exceptions to the general law of communes that prevails in that country, and are administered, in fact, by what is called "le régime du bon plaisir;" and, second, that the "régime" in question is carried into execution by the instrumentality of the organisation that previously existed. Thus, in the other cities of France, the prefects have very little power; the maires and the municipal councils, which are freely elected by the public, have, in reality, the unlimited control of the funds raised from their fellow citizens. In Paris, in Lyons, and Marseilles, however, the prefects of the department have a more direct action, and the municipal councils are nominated at the choice of the Emperor; the councils have, in the latter case, only a consultative voice, which is easily controlled; the initiative of any improvement comes from the prefect, who is all-powerful. Of course, the prefect is obliged to carry out the projects that he may form by the aid of the subordinate employés of the administration; and he is responsible, for the acts that he thinks proper to adopt, to the great tribunal of public opinion, which may be considered to be represented by the semblance of the municipal council that authorises, or not, the measures for carrying into effect the resolutions of the prefect. But this system of control is very illusory, and it in nowise insures that the resources of the towns should be laid out according to the wants of the population, or even according to their means of supporting the charges the works may involve. Hitherto, it is true, no inconvenience, or but very little, has been found to arise from this cause; because, in the first place, there had grown up in the cities of Paris, Lyons, and Marseilles, in the course of years, a state of things that made any change a change for the better; and, in the second place, because the prefects of those cities are all of them high-minded men, men of enlarged views, and men who could well understand the wants of the population whose welfare was entrusted to their care. But what would be the ultimate result of such a system, when the directing hand and head of the empire was withdrawn? It is impossible to speak in too high terms of the attention with which every want of the Parisian public, for instance, is considered. The Government is literally there a visible Providence, to interpose between the consumer and the producer; and it makes, as the French people themselves say, "la pluie et le beau temps" in affairs which we leave to the care of a real Providence, and try to shelter ourselves against as best we may. As far as they have gone, the results of the system applied by our neighbours have been satisfactory, and France has increased in splendour and real comfort in a degree which passes belief; the worst of this system is that it depends upon the lives and intellects of the men who carry it into effect, and it is always subject to the errors that they may commit in their appreciation of the wants of the community.

But it is hardly the place here to indulge in abstract theories of government, and our business is more directly concerned with the measures adopted in Paris to carry out the immense improvements of that city. As was said, the system of government consists in, first, a prefect of the Departement de la Seine, who is a senator, and is named directly by the government; second, in a municipal council, consisting of sixty members, under the actual presidency of M. Dumas, the chemist and senator; third, of the different members of the administration, that is divided into a number of services, all of which it will not be necessary to notice upon the present

* Paper read before the Society of Arts.

occasion, as they are connected with the duties of the prefect that concern other functions besides the execution of public works. The prefect, in fact, represents the town in all that concerns the action of the government, and in all legal proceedings that may be undertaken for the defence of the interests of the municipality. He is charged with the execution of the police, conjointly with the prefect of that department; with raising the taxes, and the execution of the conscription, with the service of the national guard, with the administration of the hospitals, the public assistance, the public education, and, in general, with all that relates to the government of the town. In this he is assisted by the "maires" and "adjoints" of the different arrondissements of Paris, who are also nominated by the crown, but in nowise subject to the election of those they rule. As the division of Paris into arrondissements and quartiers will very frequently come under notice in the sequel, it may be as well to say here that the city comprises twenty arrondissements, each of which has a maire and his adjoint, and is further subdivided into four quarters in each arrondissement. As the duties that are fulfilled by the maires and adjoints are exclusively confined to their magisterial functions, excepting in so far as they prepare the lists of the electors, there is not much inconvenience found to arise from their not being themselves elected; but, as will be seen in the sequel, there are grave objections to the municipal council being nominated, and holding their office at the will of the Emperor.

When, under this system, it is determined to execute a great public work, the course adopted is as follows:—The minister in whose functions the building enters (for in France the Minister of the State, the Minister of Public Works, the Minister of Worship, the Minister of War, have to do with as many of the buildings of Paris as the Prefect of the Seine) causes his employes to study the project, make the preliminary estimates, attend the inquiry that is held into the necessity for the execution of the work, and then presents his estimate, and all the documents connected with the inquiry, to the chambers, in cases where the national funds are concerned, or to the municipal council when it is only a question of the funds of the locality. In Paris, the course is for the prefect to transact this business with the chiefs of the department of the "Voirie," at this time under the direction of MM. Tronchon and Deschamps, who are specially charged with the service of the setting out and regulating the streets of the city; but in every case the initiative proceeds from the prefect, who lays out the new lines of streets according to his own ideas upon the subject, and who is alone responsible for their direction to the Emperor. The project is then submitted to the Emperor in council, who decides whether it is of a nature to require the application of the law of public utility. The council of state orders an inquiry into this branch of the project, and, after hearing the various parties affected, it generally decides upon the question in favour of the prefect's design, and issues a decree to that effect. The project is then brought before the municipal council who decide upon the opportuneness of the execution, and have to provide the sums of money that are required. The deliberation upon the project thus presented by the prefect to the municipal council is a mere *pro formâ* piece of business; almost invariably the decision of the council is that the work shall proceed, and then the orders are given to mark out the ground, and to proceed to ascertain the indemnity that is due to the proprietors, who are turned out. This is an operation that is done at once, after due notice has been given; but the purchase of the land goes on after the construction of the new street has been decided on, let the estimates be ever so much exceeded. Upon the completion of the formalities, the prefect takes possession of the ground, and he either yields it to the Compagnie Concessionaire, with the understanding that they will pay for the sewerage and water supply, the works for leading the gas to the public lamps, the execution of the roadway and footpaths, and the construction of the houses according to a plan determined upon; or he proceeds to the execution of these works by his own agents, and he, of course, receives the proceeds of the sale of the land that is reserved for building purposes. The latter course was adopted in the commencement of the great works of improvement in Paris; the former seems now the favourite with the prefect, as it leaves the municipality free to employ its credit and pecuniary resources, wherever he may think most desirable.

The execution of the works is divided into several departments, which consist of—first, the Voirie; second, the Service des Eaux et Egouts; third, the Service du Pave; fourth, the Service des Promenades et des Plantations; 5th, the Service des travaux d'Architecture; sixth, the Superintendent des Logemens Insalubres; seventh, the Service des Ingenieurs des Ponts-et-Chaussèes; and eighth, the service of the Carrières.

The first of these comprehends all that relates to the plan of Paris, and to the proposed rectifications thereof. It embraces the setting out of the new streets; the fixing of the lines that are allowed to prevail; the projections on the public way; the numbering of the houses, the acquisition of buildings that are acquired by means of expropriation; sales and exchanges of land, &c. There are employed in this branch of the administration, in addition to the two gentlemen already named, seven surveyors or "geometers;" nine surveyors who are charged with topographical works; four chiefs of sections, and a countless number of subordinates, who are charged with filling up the details of the service. As Paris is now undergoing the process of being surveyed thoroughly, the number of employes in this department is very considerably above the average; but the numbers given may be taken as representing the normal composition of this branch. There are, in addition to it, twenty architects "voyers," and twenty assistants, or two to each arrondissement, who have, in their functions, the observance of the laws that regulate party walls, and the numerous cases that continually arise with respect to air, ventilation, and light, and to the right of support by the neighbouring property, that are always the source of complicated action in the interior of great towns. It is this branch of the service, as was said before, that the prefect consults in preference to the rest, for all that relates to the improvement of the town.

The services of the "eaux et egouts," of the pavement, and of the promenades and public parks, are discharged by engineers of the Ponts-et-Chausseees, or of the state, who are specially detached from the ordinary service, and are allowed to enter into the employment of the city of Paris, whilst they retain their rank and privileges as members of that body. I think it necessary to dwell a little upon this point, because an imaginary distinction has been sometimes drawn between the town engineers and the engineers of the Imperial Government. All the engineers of Paris are members of the Corps Imperial des Ponts-et-Chausseees, whilst the works of the Louvre, which in a recent discussion before the Committee of the House of Commons were especially alluded to, are all under the direction of M. Lefuel, who is an architect, and who is responsible alone for the success of them.

However, the three services named are united under the control of, at present, M. Michal, Inspecteur des Ponts-et-Chausseees, who has the general supervision, and regulates, as the last appeal, the various departments. He has under him, M. Belgrand, Ingenieur-en-chef de 1re classe who is charged with the "Service des Eaux et des Egouts," or in fact takes the management of all that relates to the *underground* works of Paris. Then M. Homberg, Ingenieur-en-chef de 1re classe, and M. Rozat de Mandres, ingenieur-en-chef, are charged with the superintendence of the paving, roadway, and footpaths, or everything on the *surface* of the ground; and M. Alphand, Ingenieur-en-chef de 1re classe, is charged with the plantations, seats, sheds, lamps, and generally with everything *above* ground; so that these four gentlemen have very distinct provinces, and yet they are all of them subject to the control of M. Michal, who has the title of Director of Public Works. M. Michal receives from the prefect, after the inquiry into the expediency of the proposed lines of communication, and the reference of them to the municipal council have been fulfilled, the indications of the direction that the lines are to follow; and at the same time the plan indicating the exact line of the properties that the city intends to buy. He then consults the engineers of the various branches of his service, and they prepare in concert a project for the sewers, the water supply, the gas piping, and the plantations; they prepare estimates and designs for the work, which are submitted to the approval of the prefect; and, if approved of by him, are at once executed. The principles adopted in these cases are to shorten as much as possible the distance between the extreme points to be connected, and to regulate the level; and it must be confessed that in the new streets and boulevards lately formed in Paris, this has been carried out with very little attention to economy in laying out the lines, or in the levels given to them; but there are occasions when it is necessary to respect a public monument, or to preserve a certain gradient in order to accommodate a sewer, that may give rise to some deviations from the strict rule thus laid down.

The engineers are, it must be added, directly interested in carrying out the works in the best manner, for they are charged with their maintenance, and their working afterwards; and as the city exercises a vigilant control over the sums allotted to this branch of the service, the engineers are kept thereby constantly on the stretch.

The bureaux that are immediately under the orders of M. Michal are not so numerously constituted as those of his subordinates, for he has only a general supervision over the works, and the engineers of the various departments prepare all the details of the execution; he has, therefore, principally to do with the accounts, and with the transmission of the orders of the prefect. In M. Belgrand's office there are three Ingenieurs ordinaires de 1re classe, who are charged with the superintendence of the works that are in process of execution, and one other engineer who is charged with the construction and maintenance of the steam engines that are employed for raising the water; the laying the new pipes that are from time to time required is performed by the engineers charged with the roadway, but under the orders of M. Belgrand, and they also exercise a control over the sewers, which come under that gentleman's direction, both for their construction and subsequent working and cleansing. As the gas pipes are laid in the soil, it follows that they also come under the province of M. Belgrand, who regulates everything that is concerned with what the French call the "canalization," or the pipes that serve to lead the gas to the places of consumption; the quality of the gas, and the manner in which it is to be burnt, form, however, part of the functions of M. Alphand, the engineer of the promenades and public plantations, and he is assisted by a host of inspectors, verificateurs, superintendents, &c., who are charged with the details of the private lighting. The details of the Service des Eaux et Egouts give rise to the nomination of a great number of employes, amongst whom the Inspector de l'Assainissement has a staff of seven assistants to superintend the communication of the houses with the drains or sewers; an inspector for the preservation of the hydraulic works that are connected with the distribution of that fluid in the fountains, the street plugs, and the pipes; an inspector who regulates the supply that takes place in the public offices and the departments of the state, eleven persons are employed in the office of the engineer charged with raising the water; twenty-eight persons are employed to receive complaints and reclamations, and to give the temporary orders for repairs of the pipes that are in communication with the private houses; 105 persons who are charged with opening and shutting off the water from the various places of distribution; and finally, fourteen persons who are charged with the superintendence of the various reservoirs. The city of Paris, it is to be observed, undertakes the supply of the water that is consumed in that town, and it is now energetically at work to improve both the quantity and quality of the sources it resorts to; in the meantime it delivers the water to a company, which undertakes the works that are required by the subscribers for water, and accounts to the town for the payment of them. The company is paid for its intervention in the matter by an allowance which it retains upon the amount of the sums it accounts to the city for. The distribution is on the constant delivery principle, but it leaves a great deal to be desired on the score of height; indeed the tenure of house property in Paris is in fact opposed to the profuse use of water we are accustomed to in England, and the supply may be said to be more municipal than it is domestic. It serves to wash the streets and to feed the monumental fountains more than it serves the household wants of the inhabitants, who, by the way, have learnt to pass over the deficiency of many things that in England are almost necessaries of life. There is a strict relation between the services of water and sewers, which in Paris has received a good solution, so far as the removal of the refuse from the streets is concerned; but the whole of this subject is so complicated, and it would lead to details of such length, that I must reserve them for another occasion. I may here mention that the city of Paris has treated for the supply of gas with a single company, on very favourable terms for both that company and itself. The affairs of the company are at present under the management of M. Gaffier, an Ingenieur-en-chef des Ponts-et-Chaussees, and M. Camus, Ingenieur-ordinaire, of the same body.

The service of the "pave" is arranged in the following manner:—M. Homberg, the ingenieur-in-chef, has under his orders five ingenieurs-ordinaires, and they have the control of a certain number of inspecteurs, usually about two for each arrondissement, a number of conducteurs and piqueurs, about four for each arrondissement, and a number of cantonniers, about forty for each arrondissement. M. Homberg is charged with the superintendence of the parts of the town that were included within the limits of old Paris, but when the limits of the town were carried back to the fortification, the paving of the districts thus included was entrusted to M. Rozat de Mandres, who has four ingenieurs-ordinaires under his orders, with the usual number of inspecteurs, conducteurs, piqueurs, and cantonniers. These gentlemen are charged with everything connected with the level of the streets, both longitudinal and transverse; they arrange the fall of the channels and the points where the water is to be delivered, and to be conducted to the sewers; they have the choice of the material that is to be used, either paving or macadam, and they fix the manner in which it is to be swept and cleansed; they execute the borders, and they have a control over the execution of the footpaths that are under the special care of the householders, unless the city thinks proper to plant them, when they pass under the control of M. Alphand. In Paris the materials used for the roadways are the grès or sandstones of Fontainebleau, the porphyry of Belgium, the quartz rocks of various localities, the meullières of the Paris basin, and the bituminous rocks of the subcretaceous formations of Seyssel, Neufchatel, &c.; for the footpaths they principally use asphalte, porphyry, and grès. The streets of Paris are models of cleanliness, and they may well bear comparison with those of London, or of any Dutch town, being managed upon a uniform principle, which our streets are deficient in. The gutters are carefully washed twice a day, and everything is removed from them before the inhabitants are abroad; and this is the more remarkable, because all the Paris houses are constructed without anything that corresponds with the dust-bins of London, so that the Parisians are obliged to deposit everthing in the shape of rubbish in the public streets. The engineer of the egouts, in fact, complains that his branch of the service is unfairly charged with the removal of much refuse that ought to be carried away on the surface; but this is a minor evil, which is amply repaid by the cleanliness and the good state of the roadways. Perhaps the street paving may be rather in a worse state than that of London is generally; but that is owing to the great expense of the materials employed in Paris; at any rate, they never expose their horses to the cruel task of wearing down the stones of their macadam—a system that prevails to a fearful extent, with loss to the parishes, be it observed, too, in our city, that boasts so much of its civilisation. In Paris the footpaths are, as was said before, under the special control of the householders, who can of course pave them in any way they think proper; except in the new streets, where the city has executed them simultaneously with the roadways, and where the houses are made liable to a payment for their repair.

The bureau of M. Alphand, Ingenieur-en-chef of the promenades and the public plantations, is composed of two ingenieurs-ordinaires and a great number of inspecteurs, conducteurs, piqueurs, and cantonniers: there are also two architects, two sous-inspecteurs, one inspecteur verificateur, and a host of clerks. The attributions of the office are the superintendence of the planting of trees upon the boulevards; the maintenance of the public parks; the establishment and maintenance of the public fountains; the decoration and placing of the public lamps; the arrangement of the market places and the standing booths for public conveyances, advertisements, &c., in so far as they are unconnected with the building; in fact, the execution of everything that is concerned with the upper part of the public ways. In the discharge of these duties M. Alphand is assisted by the ingenieurs-ordinaires of the "voie-publique," but as much as possible the services are kept distinct.

The Service des Travaux d'Architecture is an important branch of the administration, but it does not exercise much influence upon the lines or directions of communication, excepting in so far as they may interfere with the existence of monuments of great artistic and national value; and it is for this reason, principally, that the advice of the architects is taken. Under general circumstances, the architect's business is confined to executing the public buildings on the spots that are designated for them by the prefect, and they have to prepare their plans in conformity with the instructions they may receive from him, and in accordance with the limits of expense that he may judge advisable. At present, the Service des Architects is under the immediate presidency of M. Baltard, who has under him a chef de bureau, and a body of architects and inspectors charged with the maintenance of the Hotel de Ville and the various offices of the municipality. There are four architects-in chief; one of whom has the direction of the buildings that are connected with the maintenance of public peace and the administration of justice; another, the building and maintenance of the places connected with public education; another, the places connected with commerce and the administration of the municipal laws and funds, such as the mairies, tribunals of commerce, octrois, &c.; and the fourth, the superintendence of the religious structures. They are assisted by four controleurs and about fifteen local architects, and two local architects are also named to superintend the departmental buildings; they have, as is usual in the French administrations, numerous subordinates; and there is quite an army of architects, that is charged with the construction of new buildings; the number of these is not less than thirty-three at the present time, and it is calculated that the town has not less than 250 architects, conducteurs, piqueurs, and superintendents, in its employment—the greater part being permanently engaged.

The superintendence of lodgings constitutes but a small branch of the administration of Paris, and it does not come into play at all in the improvements that have lately been carried on in that city; so that it will suffice merely to mention, in passing, that this object forms one of those that seriously occupy the attention of the prefect and of the municipal council. The works that form part of the attributions of the Ingenieurs des Ponts-et-Chaussees, more directly concern the inhabitants of Paris, because they often blend themselves with the works executed by the engineers of the same body detached for the service of the town. Generally speaking, the works that are required to connect the capital with other countries, and with the chief places of the several departments, the lines of internal navigation and the railways, fall under the care of the Ingenieurs des Ponts-et-Chaussees; and we therefore find that the service of the Seine is organised in several bureaux, that is to say, the ordinary service, the service of the navigation, the service of repairing and maintaining the bridges, the service of the superintendence of railways. In this number are included about eight ingenieurs-en-chef, and about twenty-four ingenieurs-ordinaires, who discharge duties that are very variable, and are rather indefinite in their nature, because they somewhat interfere with the duties of their colleagues; however, although the engineers of the state are under the immediate control of the minister of public works, they are nevertheless, to a great extent, subject to the Prefect of the Seine, whose consent is necessary for any great operations that they may be called upon to perform. The same thing may be said of the service of the engineers who are charged with the superintendence of the works that are required for the consolidation of the quarries under Paris; these are composed of the engineer-in-chief of the mining engineers and two ingenieurs-ordinaires of the same body, and their duties consist in the superintendence of the catacombs and the foundations of the public buildings. It is found necessary to organise a special service charged with this duty, which the prefect is bound to consult whenever a new line of communication is to be established; but it is only as a precaution, and to insure the safety of the buildings about to be erected. All the last-named branches of the administration only have the right to interfere with the prefect when his measures are likely to trouble the public convenience or security; and therefore they are only mentioned incidentally on the present occasion.

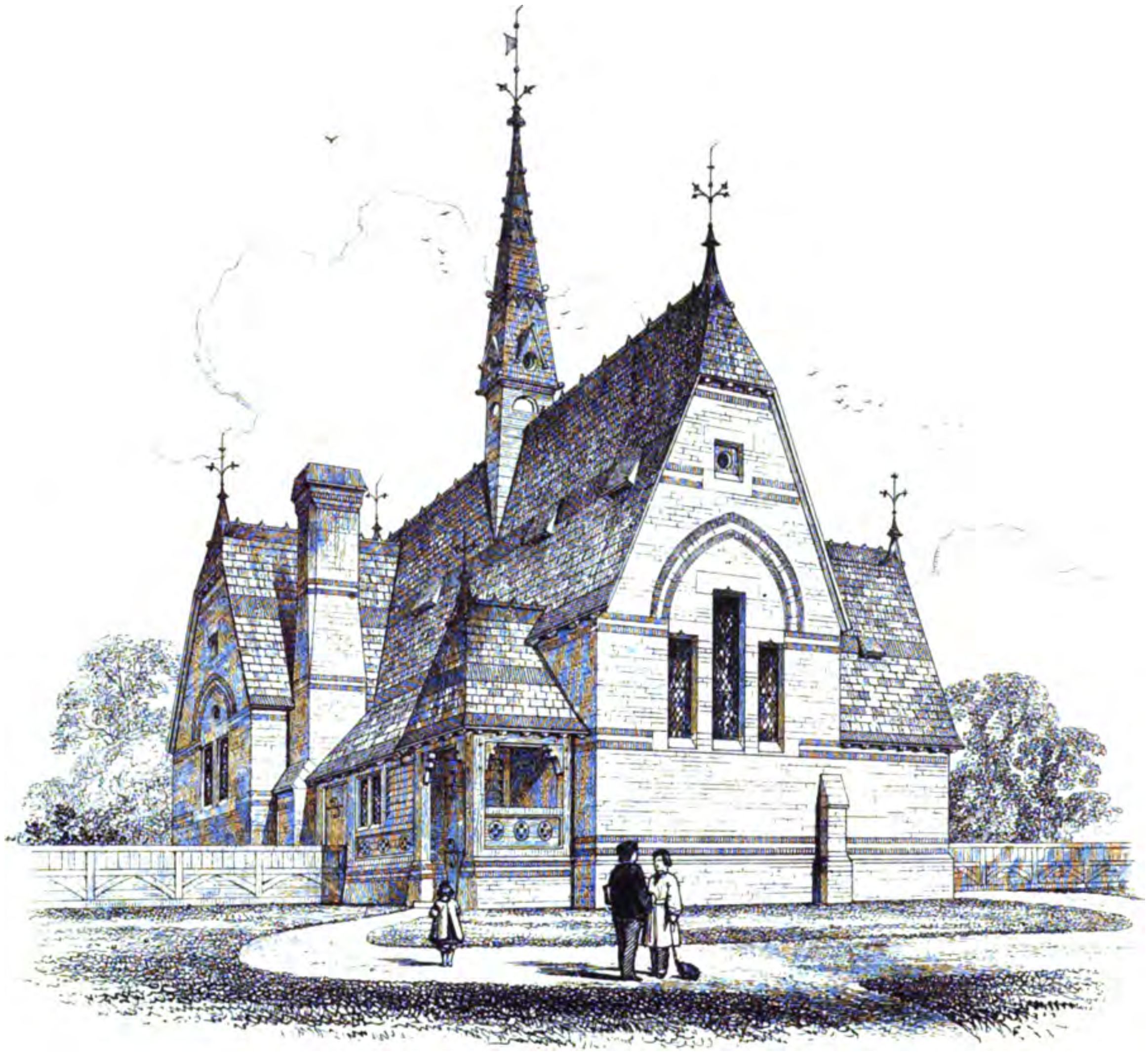
But it remains for us to ascertain how the prefect manages to provide funds for the total change that he is effecting in the plan of Paris, and in the improvements there carrying out under his energetic management. In the first place, the revenues of the town are of themselves very large, and they have been pledged long since to meet such of the expenses as are authorised by the government; and in the second place, the city of Paris has entered upon the abuse of its credit, by the creation of a species of floating debt, that I think will end in bankruptcy. The yearly receipts of the town of Paris are (or were last year) 155,590,040 francs, or £6,223,600 nearly, which are raised from a population of not more than 1,667,841: and this, it must be understood, only represents the sums that the inhabitants pay for their local taxation; for the government taxes, that are levied directly from the payer, are quoted at the sum of 33,411,718 francs, or the additional sum of about £1,335,468. This sum of about six and a quarter millions would amount to an annual payment of about £3 15*s*. per head of the population, and it cannot be a matter of surprise that the expense of living in Paris is becoming rapidly unbearable. The incidence of the taxation is no doubt disguised by reason of its indirectness, but this only makes it more heavily felt by those who do consume the articles taxed. A man pays in Paris according to his consumption, not according to his means; and thus the rich man escapes contributing to the state. The poor man is forced to pay more in proportion than his neighbour. Of course Englishmen have nothing to do with the manner in which the French may levy the revenue that they may require, but it is right to call attention to the radical unfairness of the system, when so many people here are clamouring for the introduction of a similar one amongst ourselves. As it is, however, the rate of local taxation may be taken at nearly 50 per cent. on the rental of the inhabitants of Paris, including, however, all the relief of the poor, the expenses of the hospitals, the schools, &c., which with us are left to the care and charity of private individuals.

But it is to the creation of a description of a municipal floating debt that the most impartial people look with the greatest dread. The city of Paris, even now, has a funded debt that gives rise to the payment of 13,428,746 fr., to defray the interest, and 10,314,892 fr., for the sinking fund, or nearly a million a year is thus absorbed out of the 6¼ millions raised by the town. This is not all, however. The prefect has been allowed to issue obligations in the name of the city, and for the caisse des travaux de Paris, to the extent of 80 millions of francs, or for £3,400,000; and, if reports are to be credited, so far from his being contented with that enormous sum, he has extended it to the amount of 38 millions of francs (or £1,500,000 nearly) in the case of the works undertaken in the Boulevard Magenta. It is precisely the danger of this abuse of the credit of the town that is to be feared, and it is in this respect that the absence of anything like a controlling power in the municipal council of Paris is to be deplored. As the members of this body are all of them merely government nominees, and hold their places only as long as they vote the budget that is presented to them, the municipal council of Paris becomes nothing more nor less than a body chosen to give a semblance of legality to the proceedings of the prefect; it is utterly powerless to resist or to oppose any measure that he may have determined. Hitherto there has been no such result as was to be expected from this ignoble parody on municipal government, and Paris has gained in healthiness, in beauty, in convenience; in fact, in everything that tends to make life valuable in large towns.

(To be continued.)

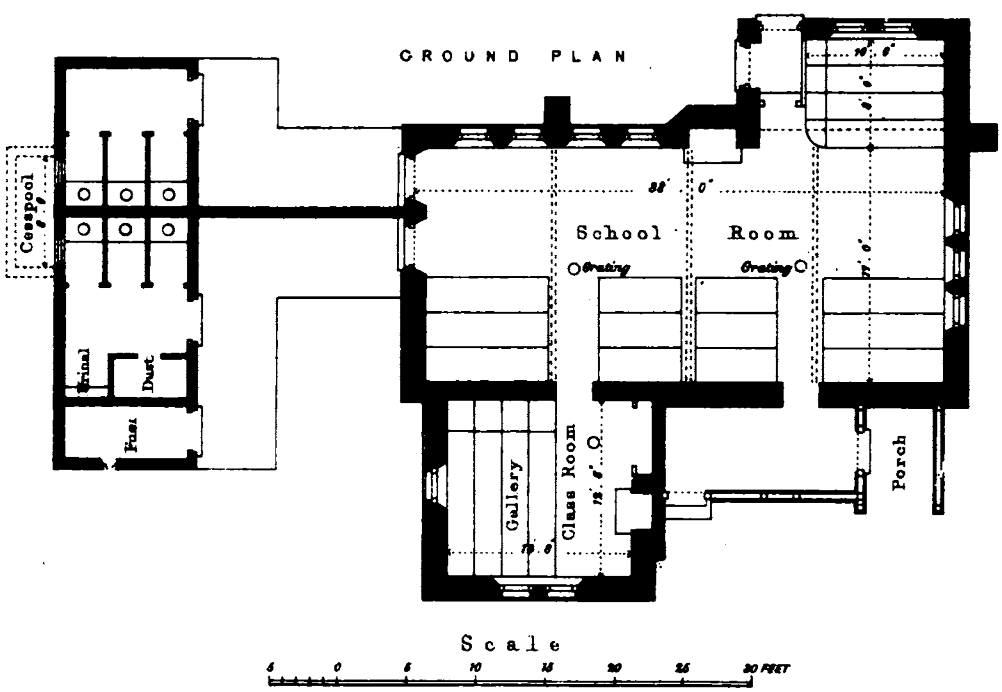
The Early English Gateway, Smithfield.—The old entrance-gate to St. Bartholomew's-close, from Smithfield, a specimen of the Early English style, has been for a many years, in a great measure, concealed by an adjoining house,—one side of the gate being, in fact, snugly inclosed in a tailor's shop, whilst the top part of the gate, sculptured with its characteristic mouldings, serves as a support to the flooring of the tailor's bedchamber. The tailor's and the three adjoining houses have now bills stuck upon the walls, announcing that the whole property will be sold by auction in March; the Early English entrance-gate perhaps included. It is the opinion of some persons that the gate is the property of the city of London: if so, it is to be hoped that it will be cared for.

Royal School of Naval Architecture and Marine Engineering.—A course of three lectures, on "Magnetical Errors, Compensations, and Corrections, with special reference to Iron Ships and their Compasses," is to be delivered in the Old Lecture Theatre of the South Kensington Museum, on Thursdays, March 9, 16, and 23, 1865, from four to five o'clock, p.m., by George Biddell Airy, Astronomer Royal. The subject will be treated under the following heads:—1. Terrestrial magnetism, and the magnetism of permanent magnets. 2. Transient induced magnetism of iron. 3. Sub-permanent magnetism of iron. 4. Correction of magnetic disturbing forces. 5. Magnetism of ships, especially of iron ships, and correction of their magnetic disturbing forces on the ship's compass. At the close of each lecture, the Astronomer Royal will wait to give separate explanations to any individual members of the class. Though single lectures may have previously been given, it is believed that this will be the first course of lectures on this important subject which has been delivered in the country.



N. W. VIEW OF SCHOOL. RINGSFIELD, SUFFOLK.
E. L. Blackburne, Arch^t.

GROUND PLAN



J R. Jobbins

SCHOOL, RINGSFIELD, SUFFOLK.

(*With an Engraving*).

This is a small mixed school, designed for sixty larger children and twenty-eight infants. It comprises, as will be seen on reference to the plan, a school-room 38 feet long and 17 feet wide, with infants' gallery at the one end, and a class-room 13 ft. 6 in. by 12 ft. 6 in. projected from the other; the necessary closets and other conveniences being behind, and connected by a covered-way with the back entrances to and from the respective playgrounds for girls and boys. Attached to the gallery building, or rather, forming part of the same, is a small porch acting as a separate entrance for girls and infants, as well as for school-mistress, if desired. On the opposite side of the school-room is the boys' or general porch of entrance, with hat and cloak-room leading therefrom to the school, and to the boys' playground, which, as well as that of the girls, is separated from the front ground of the site —laid out as garden—by a light timber fence, of a character corresponding with the general style of the building. The material for the walls is red brick, relieved by bands of black and white brick. The springers to arches of doors and windows and the sills of the latter, are stone. The roofs are covered with green Westmoreland slate, with bands of blue Bangor, and crested with ornamental ridge-tile. The timber work is fir worked fair and stained and varnished. The roofs are open internally to the ridge and plastered between the rafters, and ventilation is obtained from the dormers shown therein, and from the circular lights in the upper part of each gable. The floors of the school-room, class-room, and gallery are wood, those of the porches and cloakroom, tile in pattern. The windows are glazed with flatted sheet glass in casements, hung to open above head. On other points of the design and treatment, the view and plan will be sufficiently explanatory.

THE PEOPLE'S SHARE IN ART.

The following address was delivered by Mr. Beresford Hope, at a meeting of the members of the Architectural Museum, at South Kensington, on the occasion of the distribution of prizes to art-workmen:—

Mr. Hope said that, on previous occasions of a similar nature, he had made some general remarks on questions of artistic interest, having reference especially to the objects to promote which the Architectural Museum was established. At the opening of the session of 1863, he had endeavoured to explain the peculiar phase of art which they were associated together to support,—not art simply, nor architecture simply, but an intermediate something which they might call architectural art. Last year, having established what architectural art was the year before, he took up the art-workman's position—the position of the men who were the executive in the execution of architectural art—the art-producers: he now proposed to regard the whole question from another point of view, and to deal with it not so much as regarded the advancement or trade profit of the art-producer, as from the point of view in which the interest and advantage of the art-consumer are concerned. He proposed to speak of the people's share in art; the share of those persons some of whom might be able to practise more or less of art, but to do so for their own amusement and edification, and not as their calling in life. He desired to place before them, plainly and emphatically, a general test for a general qualification for art—as not one of those things to which they ought to be indifferent—one of those things which, as the world was now constituted, might or might not exist in a nation; but as a thing which ought to exist, if the nation meant adequately to fulfil its mission amongst the other peoples of the earth in a social, moral, intellectual, and material point of view.

They should first inquire how far it was desirable or necessary to the well-being of a people that a general appreciation of art should be diffused; next, how far it was desirable towards this diffusion of taste in art that facilities for making acquaintance with art should be offered to the general public. How far, in other words, should they take steps, not only that persons should appreciate drawing, carving, and so on; but also to a certain extent be converted into carvers and draughtsmen, although carving and drawing might never be more to them than an amusement, or, at the outside, a very temporary and occasional employment. And, thirdly, he would apply the solution of the two questions to peculiar circumstances of their own institution. First, how far ought a nation as a nation, and how far ought the individuals of that nation, to endeavour to make a general appreciation of art in all its branches—painting, sculpture, &c.—the general property of the people; not merely of the highly educated classes, but of those whose education and techincal knowledge were comparatively limited;—in short, how far ought education to be the education simply of the eye, and not so exclusively of the memory and the intellect. The question brought them back to principles of a deeper and wider character than mere consideration of artistic beauty. It resolved itself at once into that great first principle which all those who studied the philosophy of the human mind in on narrow, or bigotted, or dry spirit, were united in asserting—namely, that for the healthy development of the mind, the imagination, no less than the reason, must be cultivated.

This is an age in which science has made gigantic progress,—an age in which the machinery of literature, so to speak—printing, journals, public speaking—had attained a position and acquired a power such as no previous time furnished any instance of. All these were, in their way, antagonistic to the development of the imagination; but on the other hand, they were good and right in themselves, How, then, was the imagination to be fostered? In former time, more rude, and perhaps more stirring, the imagination was fostered through the means of the memory, and popular poetry and ballads. Heroic action, except in time of great refinement, threw itself into the form of lyric or ballad poetry. The Homeric poems were the form in which the Greek mind treasured up for ages those gallant feats which it was fondly hoped were not altogether fabulous. The Romans had their ballads; such as those which Macaulay, in his "Lays of Ancient Rome," had attempted to revive. The Border forays, before the union of England and Scotland—although they only concerned cattle-stealing cases, which a justice of the peace would dispose of now —produced the ballad of "Chevy Chase" and its compeers. In Ireland, the influence of ballad poetry upon the imagination of the Celtic race was very great; and the treasures of the ancient poetry of Brittany had lately been displayed by the facile muse of Mr. Tom Taylor. Coming down to the middle of last century, they knew how amongst the then half-civilised people in the Highlands of Scotland much stiring poetry contained in the Jacobin ballads had been enshrined. But take one more century and its heroic events—the great contest of right against wrong —the glorious, scientific, and successful feats of British arms; they only practically exist for us in the one ballad, "The Burial of Sir John Moore." Waterloo was unsung; the Crimean War produced only Tennyson's "Charge of the Six Hundred;" the Indian Mutiny, although fruitful of incidents displaying the daring courage and heroism and devotion of the British soldier, was absolutely barren of verse; the War in America had produced a good deal of writing, but not one verse that could live. On the side of the people struggling for independence there was one touching ballad; on the side of those fighting for empire there was the dolorous ditty, "John Brown's Body is mouldering, and his Soul is marching on."

Where, then, did the present generation stand? Were they given over, body and mind, to the steam empire? Had the iron of the railway entered into their soul? Where is the food on which the imagination might be matured? The answer was two-fold. Amongst those who had the time and means of obtaining a classical education there was still the system, and he trusted it would long continue, of becoming acquainted with the classic authors. He might be asked, what had a classical education to do with Gothic art, of which they were admirers? Well, he was treating of art from an educational, and not from a technical, point of view; and next, it was in the name of Gothic art that he claimed its pre-eminence in the literature of Greece and Rome. Gothic art had shown them the more excellent way, but they should confess that that more excellent way had its foundation in the streets of Athens and Rome. One reason why they studied Mediæval art with more profit and elasticity, and less of mere pedantry than their contemporaries in France and Germany, was, that in those countries the rival Classic and Gothic schools were pitted against each other bitterly and unreasonably.

Well, it being admitted that the study of ancient literature developed the imagination, expanded the sphere of thought he asked, what were the masses, who had not time, or means, or facilities of learning these things, to do? What equivalent was to be given for the knowledge of Classic literature? what compensation for the fresh stream of ballad and popular poetry which their rude ancestors called their own? His answer was a simple one, and it brought him to the point of the lecture:—for the masses, give freely, readily, and with an open hand, the means of enjoying art; give them plenty of opportunity of seeing art; give them the opportunity, too, of learning such simple principles of art as shall enable them to appreciate the merits or recognise the demerits of the specimens of art brought before them. It might also be asked, were they to take the rough sons of labour by the hand, and hopefully to ask them to admire that which was so different from all that came within the ken of their ordinary life, and from the spirit of their ordinary pursuits? There might be difficulty in the way, but that ought not to deter them; for they should remember that the more the forms of beauty were strange to the ordinary life of the class to which he alluded, the more ought they to put them in the way of enjoying them, when and as they could. One way in which they could do so was this, by giving them ample opportunity of studying copies, if they could not study the originals, of the masterpieces of art of a past time: and next, by keeping up a brisk supply of creditable art of modern production, in and around and amongst them. If they banished ancient art, they would cut off a great connection with the past, and an important branch of art education; on the other hand, if they confined themselves to the reproduction in casts and models of old masterpieces, they would not infuse the breath of life into the existing body. Modern art might be inferior to ancient, but it was their own; it was the form and embodiment of the day in which they lived; and unless they fostered the school of art of their own time—unless they were forbearing, and not too exacting—unless they encouraged it in its first tottering footsteps, they would fail to fulfil a duty they owed to the time in which they lived. In short, they should give the people museums and schools of art, and something more; scattered up and down, in the highways and byways of their towns and villages, they should have the forms of sculptured art; in their public buildings they should have specimens of painted art, so that the idea of painting and sculpture should become as household thoughts to the mass of the population. This was found to be the case on the Continent, and what was to lead to its being the case at home? Simply to go on boring with the thing until they made something like an impression; to go on displaying before the eyes of the people a successive series of representations of forms, not merely graceful forms, but forms that would recall great historical events of a past time; and again, by taking every opportunity of giving instruction in art.

The question of art-instruction for the multitude was last year, and might be again, matter of discussion in those high quarters where public affairs were seriously debated. It was, he held, the duty of a civilized commonwealth, as soon as it had appreciated the necessity and advantages of a movement towards general art-education, to foster that movement with no niggard hand, as a thing in which advancement must be made from above, even while the acknowledgment from below must, for a time, at least, hardly correspond with the zeal with which the missionaries of the movement stirred themselves up to their work. There was a great agitation now for industrial exhibitions. They had almost a plethora of art-competition all over the country. What was required still was simply a regulating mind—a broad appreciation of art, not merely in its technical details, as good anatomical drawing, good foliage grouped in naturalistic or conventional forms, good adjustment of colour, and so forth,—all these were most essential,—but also as regarded its training directly with a view to its historical and poetical interest, and affording a rough-and-ready view of other times and countries.

Take the great historical events of our own country. Where was the common Englishman, and how, to study them in pictures and sculpture? Such did not exist for the common man; and their not existing was, he considered, a great disgrace and detriment to the country. How, then, might they exist? They might exist, not only in frescoes and in sculpture, but in cheap lithographic prints, which could be circulated by the million. In the Houses of Parliament, which, with all the faults that had been so maliciously exaggerated, were still, he considered, a splendid monument, they might see this art for the people displayed. They might see it in the crypt of St. Stephen's, which had lately been so gorgeously and beautifully restored; in the hall above, devoted to the statues of our worthies; in the painting of the grand old legend of Arthur; in the historical frescoes; they could also see it in the Assize Hall of Manchester, which would shame many of the public buildings of London by its combined beauty and convenience; they could also see it in the new Orphanage at Birmingham, the donor of which had had a cloister underneath set apart as a play-ground for the children, the capitals of the columns of which were carved with fables, which were calculated to engage the minds of the children through the eye. Whether the walls of their churches would or would not be the vehicle of pictorial representation remained to be proved. Happily the idea that the Divine Being was dishonoured by representations of the great events of the Bible, that superstitious feeling, that idolatry of whitewash, was passing away, and the reasonable sense for representations of divine events was growing up. In Italy, in Germany, in Switzerland, they saw pictorial art,—of a very rude kind no doubt,—ornamenting the walls of public buildings everywhere. Unhappily, the same could not be said of Old England, with more opportunity for obtaining it now than ever before existed. And why? Partly from that superstitious dread of colouring, which had been the Englishman's bugbear until now, and partly from the want of sufficient art-education in our governing classes, both of which causes were happily dying away.

Again, if they wished to teach the people to appreciate art, they ought to teach them to do a little art themselves,—a little carving, a little drawing, and so forth. Drawing would give them a knowledge of proportion, which nothing else but a mathematical training could give them. Even children in village schools could be trained to a certain extent: they could have imparted to them instruction in the first principles of form and proportion, which would be a valuable corrective to the irregularities of the mind in after life. How it was to be done, that was not the place to discuss. He merely threw out that there was a necessity for affording to the people education in art which would stimulate and train the imaginative side of their mind, and also confirm and strengthen that harder and more practical element,—that which might be called the mathematical side of the intellect, — both of which were involved in art-training.

But how did all this apply to the art-workman, whom it was the privilege of the Architectural Museum to bring forward? It was a question of supply and demand. Once educate the people to know a little something of, and to have a taste for, art,—hold out to them grand types of artistic progress in ancient days, and good specimens of modern art, and they would create a demand for art-objects,—cheap and inferior, perhaps,—but for objects which should be supplied to meet the demand. Who were to furnish those art-objects? They might not be the venison of art, but the wholesome jerked beef at 3*d.* per lb.; and this jerked beef of art was especially what the art-workman should supply. The frescoes, as they were called, of the old churches on the Continent were run off in three or four colours: why could not art-workmen be found here to fill the churches and public buildings and vestry-halls of England with similar paintings? Why could they not do the sign-painting, which was now so much neglected,—make statuettes for chimney-pieces, vases for flowers, and many other art-objects which an art-educated people would require and demand? All these the art-workman could produce if he steadfastly stuck to his last. The creation of a general art-feeling was quite possible, and it was called for especially in this day, when materialism must be counteracted by cultivated imagination. That feeling once diffused, then the erection of museums and art-schools, and the adornment of highways and public buildings, as he had suggested, would turn to the financial advantage of the art-workman or working artist; for they could be artists as truly as those who wrote "R.A." after their names. The former might produce art objects for the million, as the latter did for the higher classes, and that was the people's share in art. They were all engaged in a great joint-stock company, of which those whom he addressed were the trustees. They might make it by their efforts, or mar it by their neglect. He asked them not to be thrown back by the fallacy that England was not an artistic nation. Those who held that idea might ask him, had he ever looked at Trafalgar Square? He had, and he admitted that there was necessity for manifesting a gigantic penitence. They might lead the way, and carry the tapers in the penetential procession; and, having done so, show their repentance by their works. They might come forward and encourage a movement towards a better state of things; not in a pedantic spirit, but with a generous appreciation of the art of all times terminating in that great art of Europe and England—the art of the Middle Ages, of which they were the heirs, and destined, he believed, to be the promoters, the improvers, and the remitters to posterity.

The prizes were then distributed to the successful competitors, as follows:—

For Silver Work.—First Prize, £10. Henry Whitehouse, jun.—Second Prize, £5 5s. Septimus Beresford.—Extra Prize, £3 3s. Geo. J. Langley.—Ditto, £1 1s. and a Book. Walter Harrison.

For Transparent Enamels.—First Prize, £7. H. de Koningh.—Second Prize, £3. Frederick Lowe.

For Opaque Enamels.—Prize of £10. Alfred Gray.

For Chinese Cloisonne Enamels.—Extra Prize, a Book. H. de Koningh.

NAPIER AND HOPE'S PLAN FOR THE UTILISATION OF THE SEWAGE OF LONDON.

The utilisation of the sewage of towns is one of the most important questions now engaging the public attention. The methods hitherto tried of precipitating the solid matters in sewage by lime and other cheap substances, do not appear to have proved commercially successful. The subject of the utilisation of sewage was recently brought before the Royal Scottish Society of Arts, by Mr. George Robertson, C.E., who is of opinion that, "almost without exception, every town which can use its sewage for irrigation, by means of gravitation alone, would find the necessary outlay to be amply repaid, Where gravitation is impossible, many towns might make use of water power for pumping; and even where steam has to be employed, this need not necessarily discourage; for pumping by steam is not such an alarmingly expensive thing, and its cost is well known. Without reference either to the value of the sewage, or the quantity used per acre of land, and applying equally to every town, there are two very important points in the consideration of the utilisation of sewage, both in a commercial and an engineering point of view. One is, the area of land which can possibly be irrigated during the course of the sewer; and the other is, the outfall for the sewage, at times when, either from wet weather, frost, or other reasons, the whole of it cannot be used on the land through which the conduit passes. The most perfect system attainable would be, to sell or utilise all that was possible on the way to the outfall, but to have the outfall itself on worthless barren land, belonging to the corporation or company to whom the sewage has been conceded. During the time when there is no market for the sewage *in transitu*, it can then be used for the fertilisation and benefit of the land at the outfall. If it should be found to pay better not to sell any on the way, then the whole can be used on the promoters' own land. When the farmers find the sewage absolutely brought past their doors, and that by using it they may, without doubt, double or treble the amount of grass grown on their meadows, they will be glad to buy it, and most probably will use all they can get. In this case, the whole can be sold for the greater part of the year, and only used on the barren lands at the outfall, when not wanted above. It is the want of a constant and certain outfall which is one of the greatest objections to some of the schemes proposed for London, especially to the one favoured by the corporation, of pumping the sewage to heights near the town, and then distributing it by hose and jet over the surrounding fields. What is to become of this mighty stream of filth when there is no market for it? It must fall back into the Thames, and render useless the present great expenditure for the purification of that river."

The plan proposed by Messrs. Napier and Hope for the utilisation of the sewage of London, is not altogether novel in its main features. In 1856 Mr. M'Clean, the president of the Institution of Civil Engineers, suggested a somewhat similar idea. He proposed to conduct the sewage of London through the county of Essex, to a point on the coast between the rivers Blackwater and Crouch, using it on the way to irrigate whatever land could be reached by gravitation. Seventy-three of the occupiers of lands in the southern division of Essex memorialised the Board of Works to adopt this project. Some years after, the Board of Works advertised for plans and tenders for the sewage; and, after some delay, the proposal of Messrs. Napier and Hope has been accepted, and a concession granted to them.

It may be mentioned that Mr. G. W. Hemans, C.E., and Mr. J. F. Bateman, C.E., were concerned in laying out this scheme, which Mr. Robertson thus describes:—

"When we examine the contour of the county of Essex, through which the London sewage is to be taken, we find it peculiarly adapted for the purpose. There is also no county in England in which the proportion of waste land is so small; and, from being wholly agricultural, the people are found in moderate-sized, and not in large towns. The part which lies in the southern portion, on the banks of the Thames and on the sea-shore, is of moderate elevation, and is a rich alluvial soil, on a subsoil of very tenacious clay. Under cultivation this produces very abundant crops of wheat, beans, and clover; indeed, the best wheat in the London market is that from the "Essex Hundreds." Most of the farms in South Essex have, more or less, a proportion of rich marsh land; the edges of the coast towards the Thames and sea being flat, and broken into creeks and islands, with great breadths of sands drying at low-water. On these fringes of flat land oxen are fed, and hay grown for winter consumption. In some parts the scarcity of water is severely felt; and throughout the county generally there is a small rainfall, perhaps ten inches less than in more western counties of England. The great mass of land land is arable at present; but meadow grasses could be easily grown, if the rainfall were to be supplemented by a supply of sewage.

Through this favourably-situated county, therefore, it is proposed to take the sewage of London on its way to the outfall on the coast; and the contour of the land is so favourable, that at least 80,000 acres can be commanded, by gravitation alone, from the main culvert and its branches. The promoters will irrigate a few fields for themselves here and there, as advertisements, to show what can be done by sewage; and I think it cannot be doubted but that the farmers will soon find out its advantage, and be ready to give a good price for this stream of wealth flowing past their doors—more especially when we consider that it is daily becoming more difficult to grow corn in this country with profit, and that stock and dairy farms are found to be more remunerative.

The present dry-weather sewage of the north side of London, with a population of 1,800,000, is 10,000,000 cubic feet a day; but the prospective sewage may be taken at 11,495,000 cubic feet. Besides this, the metropolitan board of works provides for an extra ¼ of an inch of rainfall; but the promoters only propose to take the dry weather sewage—10,000,000 cubic feet a day, or about 100,000,000 tons per annum—at present.

The main culvert is to tap the northern main outfall sewer of the metropolitan board of works at Abbey-mills, 3 miles from London, receiving the sewage there considerably above the level of high water. The culvert then runs for a distance of 6 miles, when it is joined by a branch conduit from the Barking outfall reservoir; it then passes on for a further distance of 22 miles, sometimes in cutting, sometimes on embankments, until it reaches the head of the navigation of the river Crouch, at Battle's-bridge, in Essex, 28 miles from the commencement at Abbey-mills. Up to this point the sewer consists of a circular brick culvert, 10 feet in diameter, as much as possible half in, and half out of, the ground. The culvert will take 9500 cubic feet per minute: but with the present dry-weather sewage it will only have 7000, and only be three-quarters full. The reason for starting the main culvert at Abbey-mills, and not at the Barking outfall, is to take advantage of the higher level of the sewage at the former place. The level of the bottom of the culvert at Abbey-mills is 6 feet above Trinity high-water mark, and from thence it falls gently for more than 3 miles. The level of the ground then requires that the sewage be lifted up 20 feet by pumps; and, between the ninth and tenth mile, it has again to be pumped up for 12 feet. Previous to this last lift, however, the main culvert is joined, near the sixth mile, by a 5-feet branch from Barking outfall reservoir, the sewage from which has to be raised a sufficient height to enable it to join the main culvert. If the prospective sewage be taken at 11,495,000 cubic feet per diem, the main culvert at Abbey-mills will accommodate 10,294,500 cubic feet, leaving 1,200,500 cubic feet for the Barking branch.

From the ninth mile, the sewage will flow by gravitation to the sea, with a fall of about 1 foot per mile. This, it is calculated will give sufficient velocity to prevent deposit, considering the light nature of the suspended matters in sewage, after having been churned up by repeated pumpings. The bottom of the culvert at the sea will discharge at such a depth below high-water level as to command the whole area of sands to be reclaimed.

At the twenty-eighth mile, where the conduit reaches the river Crouch, it branches off into two culverts—one of 8 ft. 3 in. in diameter, leading to the Maplin or Foulness-sands, on the south of the Crouch; and the other, of 6 ft. 9 in. diameter, leading to the Dengie-flats, on the north of the Crouch—the lengths being 16½ and 18 miles respectively. Should it be determined to give up, or postpone, the Dengie position of the scheme (the flats there being almost too rich in alluvial deposit), and increase the area to be reclaimed on the Maplin-sands, then the culvert will be taken there with the full diameter of 10 feet. The total distance from Abbey-mills to the Maplin-sands is 44 miles. The Dengie-flats and Maplin-sands are extensive foreshores on the east coast of Essex, dry at low-water, and several miles in width by about twenty of aggregate length. Portions of these vast plains of sand, mixed with alluvial deposit, are to be reclaimed from the sea by embankments (similar to those which are common in Lincolnshire, Holland, and other countries), to the extent of about 7500 acres of the Maplin-sands, and 4500 acres of the Dengie-flats—12,000 acres in all, at first. The sewers will be discharged over these areas by gravitation; and the effect will undoubtedly be, that the salt and barren sands in a couple of years will be freshened, and soon after capable of growing as rich grass as that grown at Craigentinny. The only hand labour required will be the mere keeping in order and cleansing the water channels—a very trifling expense, indeed, compared with that of the hose and jet system, favoured by the corporation of London. If the whole sewage be put on the 12,000 acres, it would give upwards of 80,000 tons per acre; one-half more than is required as a maximum. So that the company can either sell their surplus on the way, or use it on an additional inclosure of the sands, and yet do ample justice to their property at the outfall. When we consider that 80,000 acres can be commanded by gravitation alone from the main culvert and its branches, there can be little doubt of a constant and profitable market for the surplus.

Though grasses are the most profitable crops yet discovered to which to apply liquid sewage, additional experience may prove, and probably will prove, that it can likewise be profitably used for cereals and roots. But, in the latter case, there must be times during which the application would manifestly be injurious; and we must therefore look to grass meadows, if we wish to have a constant and steady demand for liquid manure.

Where the branch culvert crosses Barking-creek, and at the river Roach, which is an arm of the Crouch, syphons will be necessary; and they will be laid double, so that one may be cleansed while the other is in use. The sewage can always likewise be turned into the Thames, for short periods, when repairs are required.

The estates to be reclaimed are to become the property of the company, and will be entirely under Italian rye grass and meadow grasses, for dairy purposes and for fattening cattle.

It is to be noticed that, in this scheme, *every kind of theory* may be tried: large quantities applied to sandy soils, or small quantities to clayey and arable land; or any other plan which may by experience be found to pay best. By intermediate lifts on the clay lands, small dressings by hose and jet may be applied. There is also the advantage of a thinly populated country for the sewage to flow through in its covered channels, and a most out-of-the-way part of the coast for it to be discharged upon. Arrangements will be made by reservoirs, or otherwise, for supplying the farmers who require either a constant, or an occasional supply of manure; those who may consider it worth while to lay out their land as sewage farms, and those who may desire to take a more limited quantity of liquid in times of drought, or to start a hay crop after a first cutting, or for transplantation of cabbage and mangold, or any other market garden purpose.

Mr. Hemans estimates the cost of the culverts at £1,600,000; the pumping stations at £72,000; and the embankments and contingencies at £428,000—total estimate, £2,100,000. Should the Dengie branch be abandoned, the saving will be £450,000; culverts being £350,000, and embankments £100,000.

The annual cost of pumping he estimates at £10,000, with £300 per annum for every additional foot it may be found desirable to lift the sewage. This is only 2½ per cent. on the value of the sewage at 1*d*. a ton. or 5 per cent. at ½*d*. a ton. So that pumping on a large scale is not so very expensive, as I said before. The power required is 490 H.P. for the main line, and 60 H.P. for the branch from the reservoir.

The total expense of carrying the sewage from Abbey-mills to the sea, including 5 per cent. on the cost of the culverts, but exclusive of the sea embankments, is estimated not to exceed one-fifth of a penny per ton.

With regard to the financial prospects of the scheme; I am not quite sure as to the exact nature of the last arrangement with the Board of Works, or of the revenue calculated upon by the promoters; but it is evident that, if the sewage be practically worth 1*d*. per ton, then the gross yearly value of the sewage of North London is £417,000. If 5 per cent. on the outlay be first deducted from this, there remains £312,000 for working expenses and profit. The working expenses are calculated at £30,000 per annum; leaving the very considerable sum of £282,000 for division between the promoters and the Metropolitan Board of Works, when the scheme becomes fully developed. Even on the supposition that the sewage is worth only ½*d*. a-ton, the scheme will still be profitable to both parties, if it be carried out at the estimated expense.

Such is an outline of the plan proposed by Messrs. Napier and Hope for the utilisation of the sewage of London. When we consider the importance of the experiment to the country at large (and that it is an experiment must be at once admitted), as well as its benefit towards the purification of the Thames, we cannot but wish that it may pass successfully through Parliament. It has been well digested; the engineering details worked out carefully by eminent professional men; and it appears to offer a fair prospect of pecuniary success. The worst fault which its opponents, the corporation of London, have to find with it is, that it is founded upon too low an estimate of the value of the sewage of London, which they estimate at £4,081,430 per annum.

THE EXHIBITION OF THE SOCIETY OF BRITISH ARTISTS.

THIS exhibition—one of the earliest of the annual London season—has again opened its pleasant galleries in Suffolk-street, which are, as usual, well filled with a variety of pictures in every branch of the art. The veteran president, Mr. Hurlstone, still supplies us with his sunburnt Italian and Spanish groups, Messrs. Cobbett, Helmsley, and Woolmer, with their specialties of another type; while the names of Pyne, Clint, Boddington, Gosling, Cole, Syer, and others in the catalogue, at once introduce us to the beauties of nature, both on sea and land. If there is one department less represented than another, it is, perhaps, that of architecture; though the contributions of such artists as Messrs. Dobbin, Wood, and Brewer, are invariably interesting and worthy of study, combining as they do, the real with the artistic in their delineations. Mr. Dobbin sends four pictures, each of which bears the stamp of care and painstaking to an amount which tends to render them hard in their outline, and deprive them of much of that depth and transparency which are so essential to good effect as a whole. This is especially evident in his "Tomb of Constable Alvaro de Luna," in the chapel of Santiago, Toledo Cathedral (781); and in a less degree in each of the other Spanish subjects he has chosen. The architecture of this country has been comparatively unexplored, and is consequently but little known. The few works which have been issued in its illustration evidence, however, that there is great novelty to be gleaned in this untrodden field, to which the elaborate work just published by Mr. Street, will prove a useful pioneer.

Mr. L. J. Wood's little cabinet pictures, chiefly of continental studies, usually so numerous, are this year somewhat conspicuous by their absence. Their number has dwindled to two, (551, 621) the former, if we mistake not, another version of an old scene—"Boppart on the Rhine;" and the latter, "Braubach," also on the Rhine, appears of no special interest. Mr. Brewer, on the contrary, exhibits some capital architectural pictures, quite gems in their way, which gives cause for regret that their number is but three: (258) "at Nuremburg in Bavaria," is simplicity itself,

CLYDE DREDGERS.

Fig. 1. *Longitudinal Section*

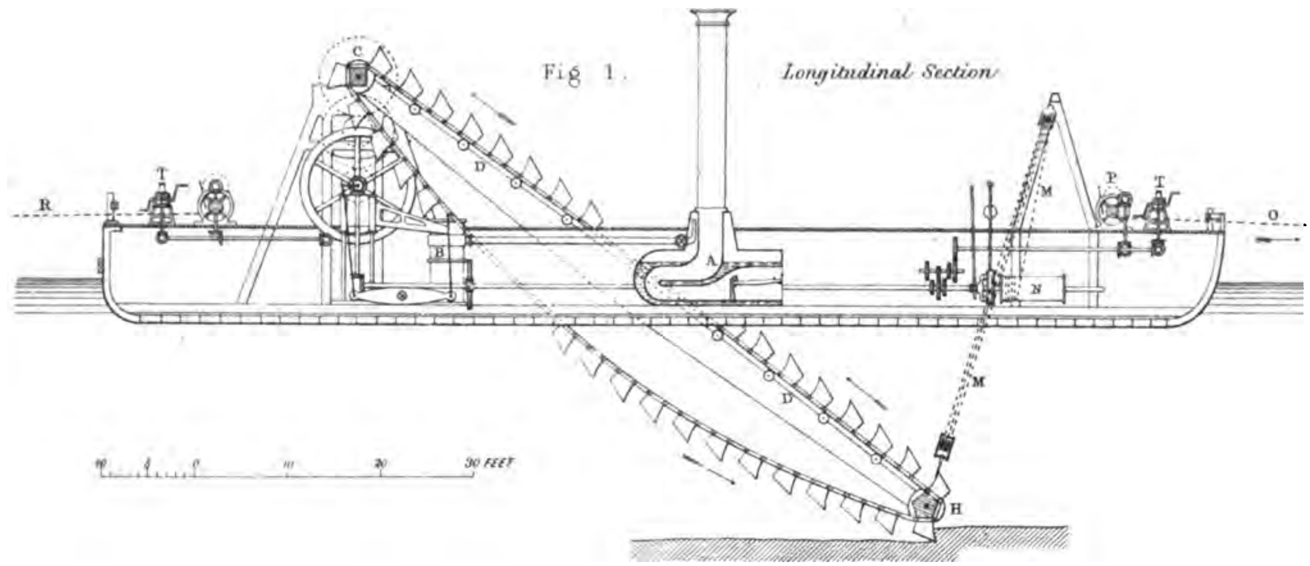
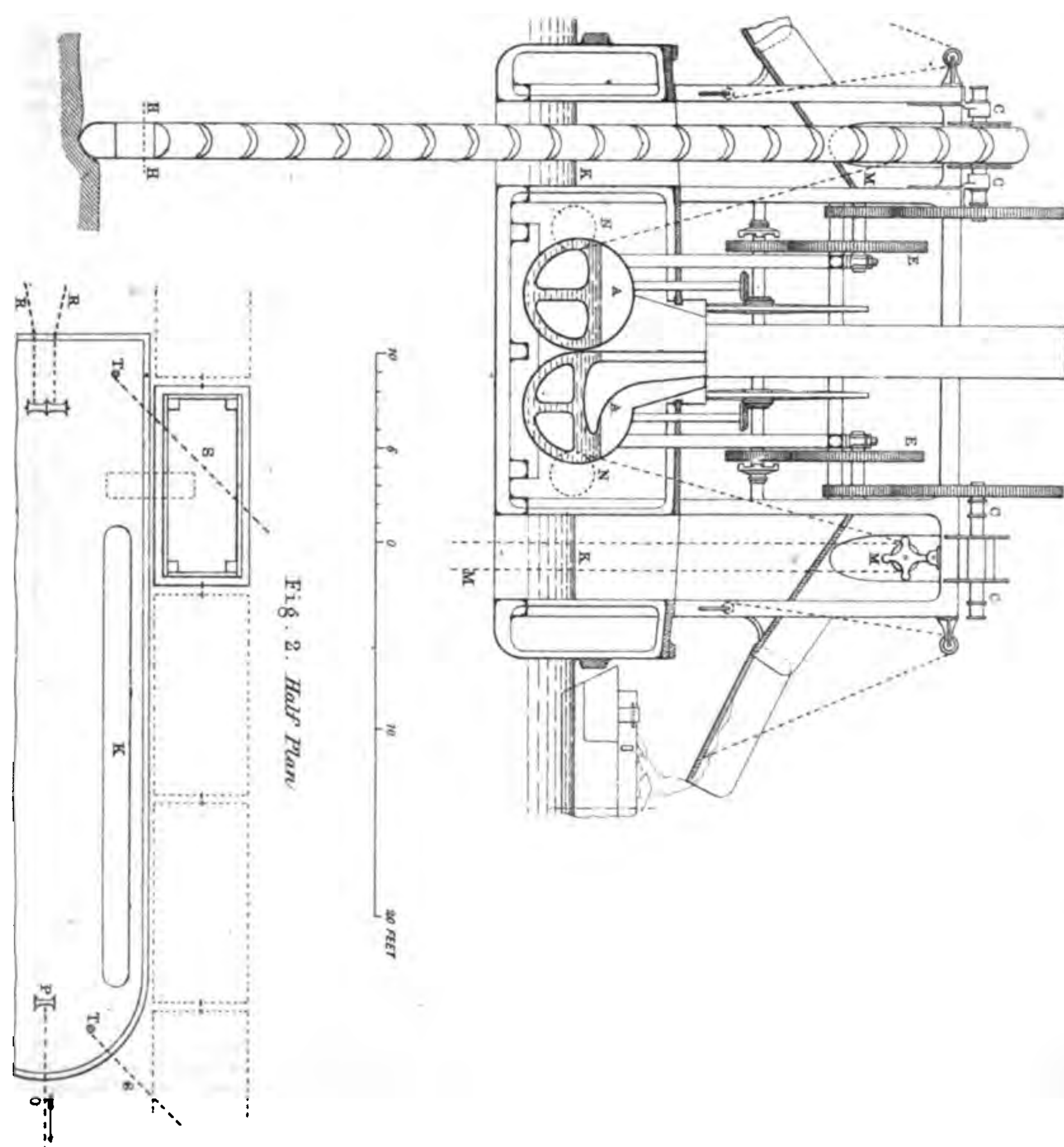


Fig. 3. *Transverse Section*

Fig. 2. *Half Plan*



J. R. Jobbins

so far as mere forms are concerned—a plain semicircular arch spanning the stream, but crowned with masonry, and flanked by turrets, &c., which give a thoroughly picturesque, as well as continental aspect to the view. Bamberg Cathedral (476) is equally good in its way, but a peep in the English city of Oxford (1007) will be regarded with greater pleasure, perhaps, than either of these. Though entitled "Oriel College," that building plays but a subservient part. It is in the foreground certainly, but so foreshortened as to afford but an inadequate idea of the building, while beyond, and in the centre of the picture, are its real attractions, the florid Gothic spire of St. Mary's Church, in close juxtaposition with the equally-renowned Classic dome of the Radcliffe Library.

The large and very fine picture by Mr. J. B. Pyne, (205), is one of the most noticeable in the exhibition, both on account of the subject itself, and the masterly way in which it is treated. It represents the Roman aqueducts from the Palace and Church of St. John, Lateran, with the Alban hills, &c., in the distance. The melancholy grandeur of the scene is heightened by the peculiarly glowing hue in which it is enveloped, while throughout the details appear to be expressed with conscientious fidelity. The old church at Bonchurch, Isle of Wight, is a well-known and favourite exercise for the brush, and has been carefully handled (231) by Mr. J. J. Wilson. Several other studies by this artist, especially of homely old-fashioned cottages, are scattered about the walls, and are deserving of notice.

In the south-east room there are a few architectural works, two (287,414) being by Mr. Pollentine, and taken at Venice. We cannot, however, say that justice has been by any means done to the subjects thus brought before us for the thousand-and-first time. The grand and Turneresque rendering of the "Church of San Georgio Maggiore, with the Dogana" (495), by Mr. Pyne, is, on the contrary, a splendid architectural work, as well as a complete study of colour. Mr. Henry's careful drawing, too (542), of the "Column of St. Mark," may here be mentioned. A view of "Gloucester" (535), by Mr. A. J. Meadows, shows the tower of the Cathedral in the distance, but it is a mere caricature of the stately outline and proportions of the original. Mr. W. Deane, in conjunction with Mr. Mann, exhibits (591) one of those street corners which he is so fond of depicting, and which he manages so cleverly in a Prout-like style. The sketch is taken at Caen. Another continental sketch, by Mr. Montague (646), shows the old tower and market-place of Ghent. Another picture by the same artist (498), is called "St. Amiens."

Reverting awhile to English scenes, we may note (800) a charming view of Arundel Castle, by Mr. Glennie, and an equally picturesque view of the "Reculvers, Kent" (795), painted on the spot by Mr. De Fleury. This latter is, indeed, a large and masterly work. Mr. Wyke Bayliss exhibits two pretentious water-colour drawings; one of part of the interior of Chartres Cathedral (868), which is overlaboured in its effect; and the same objection is due to the second picure (908), "Westminster Abbey. View from the Chancel." (*Qy.* choir?). This latter is imperfect, for though the picture is dated 1865, some important metal-work features are omitted. In a very showy drawing (978) Mr. A. E. Everitt gives an interior of the Church of St. Gudule, at Brussels, embracing the celebrated pulpit, so florid and fanciful in its design, and upon which he has bestowed due pains.

We cannot omit reference to some others among the general pictures to complete our review of this exhibition. Mr. G. Cole has been alluded to only by name as yet, but his marvellous cornfield scenes and glowing sunsets are still as unapproachable as ever. His great success in the leading picture last year has doubtless tempted him to essay another of the same class (88), and which occupies the same position on the walls. It is difficult to conceive a richer and yet more truthful bit of colouring than is here presented, and the same may be remarked of the other productions by the same hand, which are among the chief attractions of this exhibition, but especially would we point attention to one of his smaller pictures (835), called "Change of Pasture," which is a perfect gem in its way. There are two magnificent works by A. Clint; "Sunset after a Storm" (35), deserving, perhaps, the palm. Also, several delightfully cool landscapes, and shady rivers' banks, by Boddington and Tennant; clever Welsh scenery by Syer; two *genre* subjects by Haynes King, elaborated even to miniature style; several dreamy imaginings, such as Mr. Woolmer alone can evoke; some cleverly-painted animals by R. Physick; and a few select specimens of sculpture by Bell, Papworth, and others.

THE CONSTRUCTION AND RESULTS OF WORKING OF THE LARGE STEAM DREDGERS ON THE CLYDE.*

By Andrew Duncan.

(*With Engravings.*)

The improvements in the channel of the river Clyde were commenced in 1770, under the direction of Mr. Goulbourne of Chester. At that time the navigable depth to Glasgow was only 3 feet at high-water spring tides, with 1½ feet at low-water; while the high-water at neap tides did not reach Glasgow at all. The river was crossed by seven fords, one being as far down the river as Dumbuck, about 12 miles below Glasgow, which had only 2 feet depth over it at low-water. The first operation seems to have been the removal of the Dumbuck ford; and numerous cross jetties were afterwards shot out from either bank, as far up as Glasgow, for the purpose of narrowing the channel, their outer ends being subsequently connected by parallel dykes. Soon after 1798 a few ploughs, and a dredging machine worked by manual labour, were employed in deepening the shallowest places; and the result of these operations was to enable vessels drawing 6 feet of water to come up to Glasgow at high-water spring tides.

By the introduction of steam dredgers upon the Clyde, very important improvements have been effected in enlarging the channel of the river. In 1824 the first steam dredging machine was obtained, which now belongs to the town of Dumbarton, and is at work on the river Leven running out from the foot of Loch Lomond into the Clyde. By that time the Liverpool traders were coming up to Glasgow at high-water spring tides, drawing 11 feet of water. (Figs. 7, 8, and 9, Plate 9, show the depth of the channel at three different periods.) In 1831, there were two vessels drawing 13 feet; in 1836, six vessels drawing 15 feet; in 1839, one drawing 17 feet; in 1853, two drawing 19 feet; in 1860, eight drawing 19 feet; and in 1863, two vessels drawing 21 feet, arrived at Glasgow, illustrated by the diagram, Fig. 9, Plate 9. The register tonnage of the vessels arriving and departing from Glasgow now exceeds three millions annually; and the minimum depth of the river is now not less than 12 feet at low-water, with a rise of 9 feet at average spring tides and 7 feet at neap tides. The deepening and widening of the channel is still in progress, and more powerful machinery is in course of construction in order to hasten on the work. The depth which is now contemplated throughout the whole length of the river up to Glasgow is 15 feet at low-water, giving 24 feet depth of high-water at spring tides and 22 feet at neap tides.

As regards the deposit to be removed from the river bed, the greater portion of it comes from the drainage of the city, all the sewers of which discharge into the harbour, where the deposit lodges; also a considerable quantity of sand is brought down from the upper reaches of the river by the land floods, and lodges chiefly above Glasgow bridge. One of the two large double dredging machines is kept constantly at work in the harbour, the maintenance of which costs about £11,000 annually, and three-fourths of this amount may be said to be due to city sewage.

The entire dredging plant of the river consists of two large double dredgers, shown in Plate 8, and three single dredgers, making five in all; connected with which there are 350 punts, each capable of carrying 8 cubic yards or 10 tons of material; one tug steamer of 80-horsepower; and four screw hopper barges, each capable of carrying 300 tons, shown in Plate 9. During the last twenty years, 8,114,872 cubic yards or 10,143,590 tons of material have been removed by dredging; last year's work, ending June 1864, being 632,272 cubic yards or 790,340 tons.

The following is a general description of one of the large double dredgers used. (See Plate 8, where Fig. 1 is a longitudinal section, Fig. 2 a half plan, and Fig. 3 a transverse section; this is called No. 6.)

The first double dredger, No. 1, was constructed in 1851 by Messrs. Murdoch, Aitken and Co. of Glasgow. The hull is of iron, 98½ feet long, 31 feet broad, and 10 feet deep, drawing 5 feet of water. The engine is a direct-acting marine engine, with cylinder 37 inches diameter and 3 feet stroke, and makes about 33 revolutions per minute. The boiler is a flue boiler with four furnaces, worked at a pressure of 4 lb. above the atmosphere, and burning about 44 cwt. of coal per day of ten hours. The bucket frames are of timber, trussed with iron rods, and the buckets can dredge in 22½ feet depth of water. The buckets are 38 in number in each well, and each contains when quite

* Paper read before the Institution of Mechanical Engineers.

full $3\frac{1}{4}$ cubic feet. The motion is communicated from the engine to the upper tumbler by cast-iron shafting. The tumbler makes about $6\frac{1}{2}$ turns per minute, or thirteen buckets per minute; but as the buckets are never quite full, the quantity lifted when working in good material is about 10 tons in four minutes, or about 2 cubic feet per bucket. Taking the year ending June 1864, the total quantity of material lifted by this dredger was 143,360 cubic yards or 179,200 tons; and as the total number of engine hours was 2483, the average quantity lifted per day of ten hours was about 720 tons.

The material is discharged over the stern of this dredger, which arrangement was preferred to discharging at the sides, inasmuch as less room is occupied in filling the punts by discharging over the stern; but this plan has the disadvantage of causing a loss of time while the punts are being shifted after each has been filled. Another disadvantage is that when working during flood tide in the lower reaches of the river, where the current is much stronger than in the harbour, the punts become nearly unmanagable, the current forcing them so hard against the stern of the dredger, which is always moored with its bow up-stream, as to render the shifting of the punts when filled a work of considerable labour; so much so in fact, that working on the flood tide in the lower reaches of the river was avoided as much as possible.

The cost of this dredger was £8500. The crew required to work the dredger and punts consisted of eighteen in all—namely, captain, mate, engineer, fireman, bow craneman, sternman, wellman, two deck hands, cook, watchman, and seven men connected with the punts. The expenses of working during the year ending 30th June, 1863, were:—

Wages	£916	19	2
Coals	204	10	7
Stores	73	11	5
Total working expenses	£1195	1	2

and the average annual cost of repairs is about £580.

The double dredger, No. 6, shown in Plate 8, was constructed in 1855 by Messrs. Thomas Wingate and Co. of Glasgow; and is arranged so as to discharge over the sides, in order to obviate the complaints brought against the previous dredger when working in the lower reaches of the river, for which this one was principally intended and is generally used. The crew required to work this dredger, exclusive of the crews on board the screw hopper barges, is twelve in all—namely, captain, engineer, fireman, mate, cook, watchman, and six deck hands. Previous to the hopper barges being substituted for the small punts, this machine required a crew of twenty-one. The expenses of working during the year ending June 1863, the hopper barges being used, amounted to:—

Wages	£562	1	4
Coals	171	1	6
Stores	95	4	6
Total working expenses	£828	7	4

The annual average cost of repairs is about £980, being considerably more than in the case of No. 1 dredger; for as the latter is working in soft soapy sludge, the buckets and links do not get cut up so soon as if working in sand, as in the case of No. 6.

The dredger represented by us is built entirely of iron, and is 120 feet long and 33 feet broad, with a flat bottom and 5 feet draft of water; the plates are $\frac{7}{16}$ inch thick at the bottom and $\frac{5}{16}$ inch at the sides. The two boilers AA, Figs. 1 and 3, Plate 8, fixed in the centre of the vessel, are low-pressure cylindrical flue boilers, 6 feet diameter and 15 feet long, working at 3 lb. pressure above the atmosphere; and the coal consumed is about $2\frac{1}{4}$ tons per day of ten hours. The engine B is a single side-lever condensing engine, with 37 inch cylinder and 3 feet stroke, running at an average speed of about 32 revolutions per minute, and driving the tumbler shafts CC of the two bucket frames DD at the reduced speed of 6 revolutions per minute, by two sets of spur gearing consisting of mortice wheels and cast-iron pinions. Either set of buckets can be stopped and started independently of the other by means of clutch boxes worked by levers upon deck.

The power is communicated to the tumbler shafts CC through friction wheels EE, which are adjusted so as to transmit only a definite amount of power, and to slip round freely whenever the resistance exceeds that limit, from the buckets cutting too deeply into the ground or meeting with any obstacle; by this means any risk of damage to the machinery is prevented. One of these friction wheels is shown enlarged in Figs. 4 and 5, Plate 9. It consists of one ring revolving within another, the inner one F being keyed upon the shaft, and having a cylindrical recess of rectangular section turned in the circumference, $8\frac{1}{2}$ inches wide and 1 inch deep, in which fit a series of cast-iron segment blocks H. These are held in recesses in the outer ring G, and are each pressed against the inner ring by a set screw, adjusted to give the required amount of friction for driving the inner ring F, and the gearing connected with it.

The bucket frames or dredging ladders DD, Plate 8, consist each of a pair of wrought-iron plate girders, 77 feet long and 3 ft. 9 in. deep in the centre, fixed parallel to each other, with 2 ft. 3 in. space between them, and stayed together by transverse plate stays. A transverse section of one half of the bucket frames is shown in Fig. 6, Plate 9. These frames carry a series of cast-iron rollers, upon which the bucket links travel; and a cast-iron tumbler C and H, Fig. 1, at the top and bottom ends, over which the links work. Each ladder is suspended at the upper end by cast-iron dead-eyes, firmly bolted to the main framing of the dredger; through these dead-eyes the upper tumbler shaft C passes freely, and round them the ladder turns in being lifted or lowered; thus the upper tumbler shaft C does not bear any part of the weight of the ladder D. The shaft C is of wrought-iron, and works in top and bottom brass bushes in pillow blocks bolted to the main framing of the dredger. Each ladder works in a vertical well K, Figs. 2 and 3, passing through the bottom of the vessel.

There are 41 buckets to each ladder, one of which is shown separately in Fig. 10, which is a vertical section and plan of the back. The buckets are constructed of $\frac{5}{16}$ inch wrought-iron plates, bent and rivetted, with a flat back $\frac{1}{2}$-inch thick, upon which four wrought-iron bars JJ are rivetted, having eyes at the ends. These are connected together by the two intermediate links LL, three inches square, and jointed with $2\frac{1}{4}$ inch steeled pins, the whole forming a continuous chain, with 2 feet pitch of the links. The pins are prevented from turning in the eyes of the bucket links J, which are not steeled, and the eyes of the intermediate links L are bushed with steel on the wearing side. In another dredger, No. 7, which is the most recent construction, the plan is adopted of inserting a bush of hard steel $\frac{3}{8}$-inch thick into the eyes of the single links L, while they are hot; and when worn this bush is driven out and another inserted, so that the eyes of the links do not wear at all. The mouth of the bucket is made $1\frac{1}{2}$-inch thick at the point, tapered to $\frac{1}{2}$ inch at the sides, and is faced on the outside with steel $\frac{1}{2}$ inch thick welded on the plate, as shown by the darker section in Fig. 10; the mouth is shaped in a projecting scoop form, for excavating and lifting the material dredged, as each bucket in succession passes under the bottom tumbler H of the ladder, Figs. 1 and 3.

The depth of excavation of the buckets is regulated by the lifting chain M, (Fig. 1, Plate 8,) attached to the lower end of the bucket frame D, and hoisted at the rate of about 26 feet per minute by the windlass or hoisting barrel N, which is driven by a small shaft from the engine through a clutch box and friction wheel, similar to those giving motion to the buckets, and also worked by a lever upon deck. The depth of dredging is continually gauged during work by a man stationed at the bucket well K, holding a gauging rod resting on the river bottom, and having the lifting lever at hand, and also a break handle for lowering the bucket frame, so as to keep the buckets constantly adjusted to a uniform depth of cut, according to the surface of the ground. A self-indicating gauge has also been fitted up on deck, so that the captain by glancing at the position of the bucket frame may in an instant tell at what depth below the surface of the water the points of the buckets are working The greatest depth a dredger can work at is about 28 feet.

The forward motion for the cutting of the buckets is given by the bow chain O, Plate 8, which is 1 inch diameter, attached to a single-fluked anchor, weighing 12 cwt., placed about 600 feet ahead of the dredger when at the commencement of a cut. The chain is hauled in with a slow motion by the windlass P, driven by a second small shaft from the engine through a clutch box and friction wheel, and having a set of change wheels for the purpose of regulating the rate of advance according to the nature of the material that is being excavated. This rate of advance varies from about $4\frac{1}{2}$ feet per minute in soft sand to $1\frac{1}{2}$ feet per minute in hard material. The dredging is done in parallel cuts of about 120 feet length. A corresponding windlass with two mooring chains R at the stern of the vessel, gives the means of drawing back the dredger to commence a second line of excavation parallel to the former one; this windlass is driven by a small high-pressure donkey engine, with a pair of 12-inch cylinders, the dredging engine and machinery standing still during the time occupied in going astern, which is about 15 minutes, the speed being about 8 feet per minute. The two side warp lines SS, Fig. 2, extending from each side of the dredger, serve to steady it constantly during the progress of each cut, and to shift its position into the new line of excavation; they are worked by the surging heads T T, driven by the engine, or by hand power when required. The kedge anchors for these side warps are placed forwards of the dredger, so that the warp lines shall be somewhat in the position shown in the plan, Fig. 2, when the dredger is at the commencement of a cut; the warps are also passed round leading blocks when required, since it is desirable they should be as nearly at right angles to the dredger as possible. The two warps on the side next the sailing channel of the river are lowered or slacked out when any vessel is passing, but are immediately tightened up again when the vessel has passed.

The dredger No. 6, has now been at work for nine years, and has not required any repairs excepting for the wear and tear of the buckets, links, and rollers, and the usual repairs on the hull, &c. The upper tumbler however, having been found too low to allow of the shoot being placed at a sufficient height and slope for loading the large screw hopper barges, was raised 2½ feet higher. The steeled mouths of the buckets last for the year's work of about nine months, when the buckets require to be thoroughly overhauled and put in repair. The pins and links of the bucket chains last generally about four months, and are replaced from time to time as required; a supply of duplicates being kept ready on board for the purpose. The rollers over which the buckets travel in ascending the dredging ladder are of cast-iron, 1 inch thick in the barrel, with wrought-iron spindles, having 1⅝ inch journals laid with steel, which lasts about three months before being worn out; these run in small cast-iron steps with hard wood caps, fixed on the top flange of the ladder, which are readily renewed when worn out, the cast-iron bush lasting about two months, and the wood cap about nine months. Each bucket weighs 5¼ cwt., and the total weight of each set of buckets and links is about 7½ cwt. The cubic content of each bucket is 3⅞ cubic feet, and the average quantity of material brought up by each when working in sand is about 2 cubic feet. The number of buckets discharged per minute is 13 to 14, at the regular speed of about 6½ revolutions per minute of the tumbler shaft.

The total quantity of material raised per day of ten working hours varies very much according to the nature of the material dredged. Where the dredger No. 6 is at present working, about 1¼ mile below the river Leven, the rate of working is 150 tons per hour of the engine; while in hard ground the quantity may perhaps be only one half of this. Taking the entire work performed by this machine during last year, namely 303,957 tons in 2680 hours, the average work for a day of ten engine hours is 1134 tons, or 113½ tons per hour. The total quantity of material lifted by the two large dredging machines Nos. 1 and 6 during the year ending 30th June, 1864, amounts to 386,752 cubic yards, of which about 250,000 cubic yards may be considered as due to maintenance, and the remainder to the permanent widening and deepening of the channel.

The cost of dredging per cubic yard, taking the year ending 30th June, 1863, as performed by No. 1 dredger, was as follows, the dredged material being conveyed away by the punts:—

Wages, coals, stores, repairs, and 5 per cent. interest	3·02	pence.
Repairs of punts … … … … …	1·59	„
Towing punts to and from place of deposit …	2·28	„
Discharging punts by waggons … … …	12·29	„
Total cost of dredging per cubic yard …	19·18	„

The cost of dredging as performed by No. 6 dredger during the same period, with the screw hopper barges for carrying away the material, was as follows:—

Wages, coals, stores, repairs, and 5 per cent. interest	4·06	pence.
Discharging by hopper barges— Wages, coals, stores, repairs, and interest …	2·30	„
Total cost of dredging per cubic yard …	6·36	„

During this year No. 6 dredger was working near the two extreme ends of the river; and as during one half of the time it was attended by only two hopper barges in place of four, for discharging the material, much time was necessarily lost. This has since been rectified by the construction of additional barges.

The dredged material is disposed of according to two different modes. That filled into the 10-ton punts is towed down to some convenient part of the river, and discharged by barrows or wagons on to the banks or field adjoining. That put into the screw hopper barges, (shown in Fig. 10, by a longitudinal section, Fig. 11, and transverse section, Plate 9) is carried down to Loch Long, beyond the mouth of the Clyde, and deposited by opening the hopper doors U, at the bottom of the carrying space W, as showed by the dotted lines in Plate 9. At the place where the deposit is made, the water is upwards of 200 feet deep, and the mouth of the loch is about 27 miles below Glasgow; the hopper barges at present at work contain each 300 tons of dredgings, and steam from 8 to 9 miles per hour. This latter is by far the most economical mode of disposing of the dredged material, as seen by the above statement of the cost by the two methods; and the result has been so satisfactory that two additional barges are now being constructed, each to be capable of carrying 400 tons, making six barges in all. Fig. 12, Plate 9, shows the hopper barge being filled by the spout V from the dredger.

In conclusion, it may be mentioned that a larger and more powerful single dredger, shown by the accompanying model, is now being constructed for the Clyde Trust by Messrs. A. and J. Inglis, of Glasgow. The dimensions of this dredger will be: extreme length 157 feet, extreme breadth 29 feet, depth 10 ft. 9 in. and capable of working in upwards of 30 feet depth of water. The engine will be horizontal, with cylinder 44 inches diameter and adapted for a 3-feet stroke: the boiler will be tubular and capable of working to 25 lb. pressure per square inch above the atmosphere. The buckets will be 39 in number, discharging over the side; the pitch of the bucket chain will be 30 inches, and each bucket when full will contain 13½ cubic feet. The flat bucket back with the double links will be made of malleable cast-iron, with the links cast solid upon it: this construction has been found to last without requiring repair for more than double the time of the ordinary backs with rivetted links, shown in Plate 9. The bucket rollers will not require spindles, as they will have necks cast on the ends of the rollers, which will answer for the spindles. The lower tumbler shaft will be of wrought-iron, having strong rings or hoops at the journals, so that when worn the hoops can be easily removed and replaced. The only other difference of any consequence from the present dredgers will be in using grooved frictional gearing for driving the hoisting barrel that lifts the dredging ladder, instead of spur gearing with a friction wheel as previously described. The total cost of the dredger will be about £17,000.

In the discussion upon the paper—

Mr. W. Simons said he had built the screw hopper barges that were used in connection with the Clyde dredgers, and it was only within the last two years that they had been adopted: previously 350 of the square punts had been required to carry away the dredged material, but four of the barges now did the work of the 120 punts formerly attending one dredger. Each barge carried 300 tons, and was 120 feet long, 24 feet beam, and drew 8½ feet of water when loaded; the engine was 40 horse power, with 21 inches stroke, driving a screw 7 feet diameter, and the speed was the same whether loaded or empty, amounting to 9 miles per hour. The Clyde trustees contemplated abolishing the old punts altogether, and employing only the screw hopper barges for removing the material dredged. The barges were loaded in about 70 minutes, and ran down the river and up Loch Long, to a distance of about 50 miles from Glasgow, where the whole of the dredged material was discharged through the flap doors in the bottom. Hydraulic gearing was used to close and open the bottom flap doors in two of the barges, and in the others a common windlass had been applied, which had been found to work better. The total expenses of working the dredgers and barges were about £2 5s. per day, including wages, fuel, oil, and tallow: and the result of employing the screw hopper barges had been to reduce the cost of dredging from about 1s. per ton of material when the punts were used, to only 4d. per ton with the barges, making a saving of between £19,000 and £20,000 per annum. By this system of dredging it might indeed be possible, he thought, to form an inland town into a seaport, such as Preston, Lancaster, Manchester, or Paris, where there was already an outlet into the sea for carrying away the dredged material; all that was required would be dredgers and barges of sufficient power and capacity for the quantity of work to be done, since the double dredgers now at work in the Clyde raised each about 1100 tons per day in regular continuous work, as stated in the paper. About the year 1800, when the depth of the river at Glasgow was only about 3 feet at high water, the annual revenue from ships coming up the Clyde was only £3320; but in 1825, when the river had been deepened by dredging to 12 feet, allowing vessels of 300 tons burthen to come up, the revenue had increased to £9000; while in 1863, with the depth increased to 22 feet at high water, the revenue amounted to £118,000, and the river was deep enough to float the "Black Prince" armour-plated frigate of 6000 tons burthen, built by the President, the largest ship that had yet been launched in the Clyde.

The PRESIDENT inquired how long it took to discharge the hopper barges through the bottom flap doors, and how the doors were arranged to be opened.

Mr. W. SIMONS replied that only 4 or 5 minutes were required to discharge the whole 300 or 320 tons of material carried by the hopper barge. There were twelve doors, or six pair at the bottom, hinged to the iron hopper, and lined inside with timber; and the doors were let down for discharging by releasing the chains that held them up while the hopper was full. The chains passed over pulleys in the longitudinal iron girder which extended over the hopper from end to end. The barges were not confined to Loch Long in particular for depositing the material, but might go to a greater distance from Glasgow if necessary. Loch Long had been chosen because it was the deepest part of the channel near Glasgow, the depth being about 200 feet over a considerable portion of the loch, and the material could be deposited at any part of the loch.

Mr. W. E. NEWTON remarked that a dredging machine on a different principle had been used very successfully in different parts of the United States for many years, consisting of a large bucket fixed at the end of a long lever worked by chains; the bucket was lowered and dragged along the river bottom to fill it, and was then lifted by the lever, and swung round horizontally to the required position for discharging the stuff, which was let fall through a door in the bottom of the bucket into the barge beneath. The bucket raised about 26 cubic feet of soil at each stroke on an average. That appeared to him a simpler contrivance than the dredging machines ordinarily used in this country, such as those described in the present paper; it was at any rate much less expensive, and allowed of swinging the bucket round into any position required for discharging into the barge, whereas with the ordinary dredging machines the barge had to be brought to a particular place for receiving the stuff from the spout of the dredger. The gearing for working the lever was driven by a self-acting friction clutch, somewhat similar to that described in the paper, except that in the American machine the inner or driving pulley was surrounded by a bridle provided with friction blocks, which were tightened against the pulley when running forwards, but slackened in running backwards; so that the clutch simply held on in working, and was not limited to slip when the resistance exceeded a certain amount, but would transmit the whole power of the driving machinery, its only purpose being to avoid breakage from sudden jerks and to release itself for running backwards. He had seen a machine on that principle, known as the "American excavator," used experimentally some years ago on the Eastern Counties Railway in the neighbourhood of Brentwood, for excavating a cutting, and all the gearing in it was worked with friction clutches of the same kind. That description of clutch was indeed much used in America for all sorts of machinery, and was found very economical and effective in preventing breakages, by allowing the gearing to yield under any undue strain. He had never known it fail in transmitting the full driving power, and thought it would have some advantage over the friction wheel described in the paper.

Mr. H. MAUDSLAY inquired whether the friction wheel in the dredger described in the paper was found effectual in work, by always slipping whenever the buckets came into too hard ground, or took too deep a scoop into the soil, or met with any other obstruction.

The SECRETARY said he had seen the dredger at work in the Clyde, and the friction wheel was found to answer its purpose thoroughly. The screws of the friction blocks were adjusted originally to the pressure required for the ordinary working, and then continued unaltered, without requiring any further attention in working. He had seen the bucket frame lowered slightly below the proper working position, causing the buckets to bite gradually deeper in the bed of the river, until the resistance was just sufficient to overcome the friction of the blocks, when the buckets stopped while the driving pulley or ring continued to revolve outside the friction wheel; but on slowly raising the bucket frame again, the friction wheel gradually started again as the resistance diminished, and the whole worked with complete smoothness and readiness. The engineer working the dredger stated that the friction wheel had given no trouble, and there had not been any difficulty in keeping it adjusted exactly to the point desired for working. The same kind of friction clutch was also applied to the lifting gearing by which the end of the bucket frame was raised and lowered; so that all portions of the machinery were started and stopped quite gradually, the friction gear being continually called into action to meet the irregularities in the level and material of the bed of the river, and prevent any straining of the machinery.

Mr. J. SHEPHERD asked whether the material raised by the dredgers was used for agricultural purposes, as a manure, and whether it had any commercial value for such purposes, since it appeared the sewage of Glasgow was all discharged into the Clyde, and would therefore be deposited in the bed of the river.

The President replied that the quantity of sewage matter deposited in the river bed formed so very small a proportion of the quantity of the material raised by the dredgers, that it had never been thought to apply it as a manure, and it had no commercial value for such a purpose. In reference to the American dredger that had been referred to, a somewhat similar apparatus was occasionally used on the Clyde at the present time in dredging alongside the wharfs in the harbour, consisting of a rake or plough fixed on the end of a long pole, which was worked from the bank by a number of men, or from a punt on the river, and was moved along the edge of the wharfs, for clearing out the material from the face of the quay and removing it within reach of the dredger, in cases where the dredger could not be conveniently worked close alongside.

Mr. J. J. BIRCKEL observed that the depth of 13 feet at low water in the Clyde at Glasgow, and 22 feet at high water, would give a tidal fall of only 9 feet; and he inquired whether that was the actual tidal fall at Glasgow, since at Liverpool, on the same coast, the tidal fall was as much as 32 feet. He asked also, whether there was not a risk of some portion of the material deposited in Loch Long being brought back into the river by the tides, as the loch was so close to the mouth of the Clyde; in the case of the Mersey no deposit was allowed to be made at any part of the approaches to the river, for fear of interfering with the channel.

The PRESIDENT explained that there were so many arms of the sea to fill, near the mouth of the Clyde, and so many bends in the river itself, that the tidal wave did not come up to Glasgow in the same quantity as in the Mersey; and the rise and fall at Glasgow averaged therefore from 7 to 9 feet only, very seldom more. Loch Long was a blind arm of the sea, with no outlet at the further end, and no navigation through it, and there was very little tide in it; and as it was about 200 feet deep where the barges were discharged, there did not appear any probability of any portion of the deposit being carried back by the tide. From the paper that had been read it was obvious that the dredging machines employed in the Clyde had been productive of very remarkable advantages to Glasgow. From a depth of water of only about 3 feet at the begining of the present century, the river bed had now been deepened to about 22 feet at Glasgow at high water, within the space of about 63 years. But it was since the introduction of steam navigation into the Clyde that the greatest part of this improvement had taken place. The steam tugs drawing vessels up and down the river first led to the rapid deepening of the bed by dredging; and then the increase of revenue arising from the larger burthen of the vessels trading to Glasgow afforded the means of increased expenditure upon the dredging operations; thus both the depth of the river and the advantages to the city went on increasing simultaneously.

CLYDE DREDGERS

Fig. 11. *Longitudinal Section*

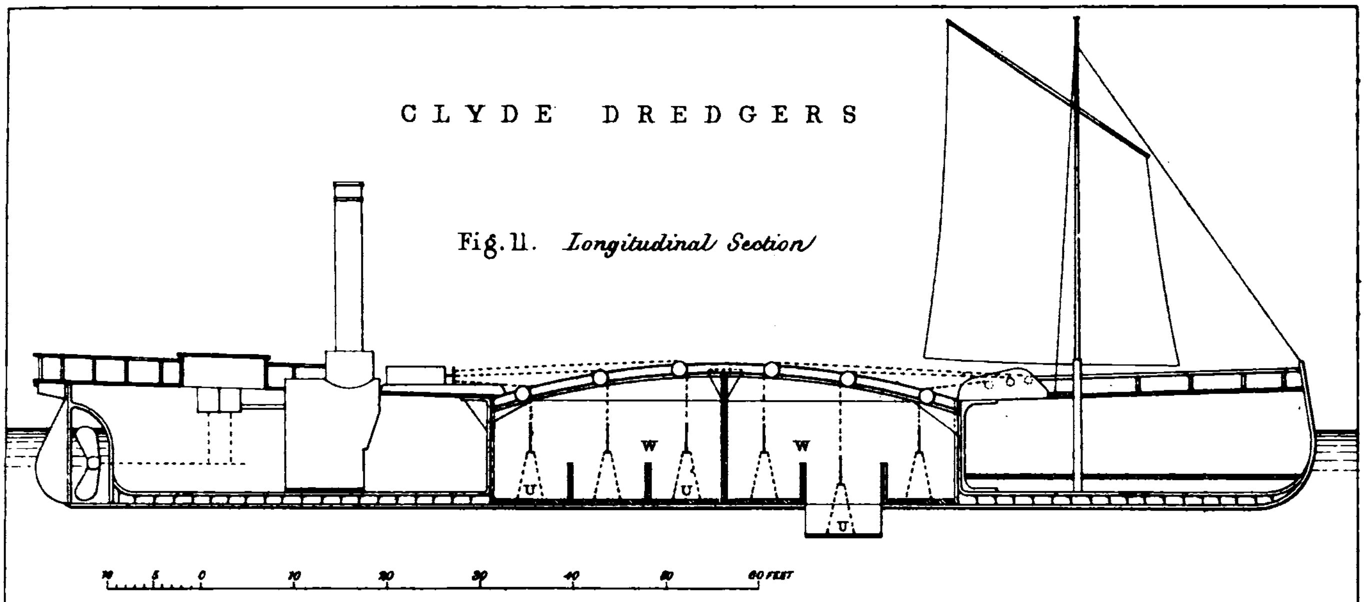
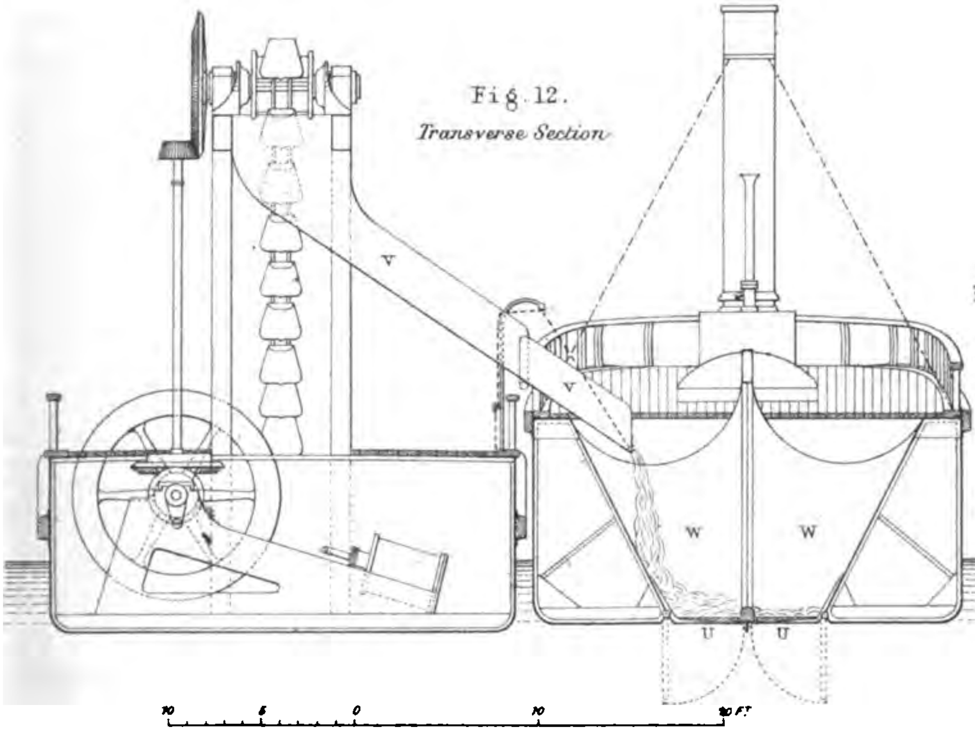


Fig. 12. *Transverse Section*



Vertical Section.

Plan

Fig. 10

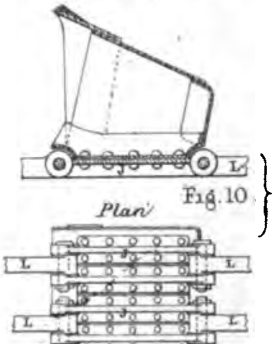


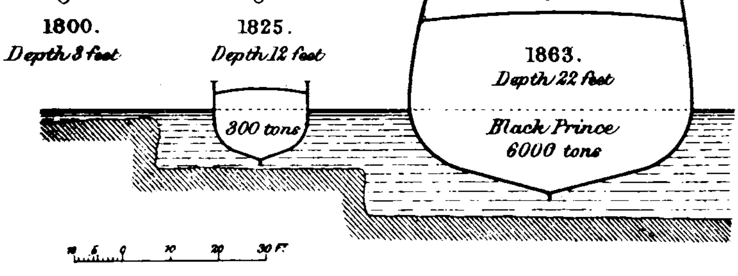
Fig. 6.

Diagram showing Deepening of Clyde by Dredging

Fig. 7. 1800. *Depth 8 feet*

Fig. 8. 1825. *Depth 12 feet*

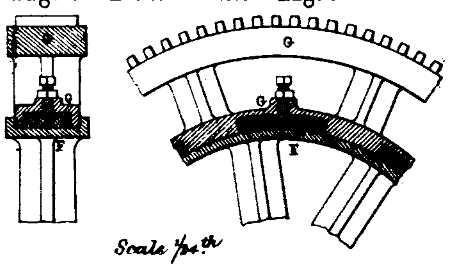
Fig. 9. 1863. *Depth 22 feet*



Scale for Fig. 6. 10 5 0 10 20 30 40 INS.

Scale for Fig. 10. 10 5 0 10 20 30 40 INS.

Fig. 4. *Friction Wheel* Fig. 5.



Scale 1/24th

J R Jobbins.

ON MARINE ENGINES FROM 1851 TO THE PRESENT TIME.*

By N. P. Burgh.

The history of the origin of the marine engine, and its slow advance, has been so often written, that I feel assured I shall not cause much disappointment if I pass over that already worn-out subject. I propose, therefore, to introduce to your notice the marine engine as it was in 1851, and the improvements which have taken place from that period to the present time. As the present paper alludes to the year 1851, it will not be deemed out of place to describe briefly the marine engines shown in the Exhibition of that date. The screw propeller was then making but slow progress, consequently the attention of our engineers was diverted from straining their talents to produce more perfect arrangements. The following examples of marine engines were exhibited.

For the paddle-wheel, the engines were arranged as follows:—vertical, angular or inclined, direct-acting, and oscillating; for the screw-propeller, a more varied and numerous collection was given, comprising disc, rotary; for horizontal direct-acting types were the following, double piston-rod, return connecting-rod, trunk; after which, annular cylinder, vertical direct-acting, inclined direct-acting, single piston-rod; and lastly, a beam engine. The largest pair of engines were 700 horse-power collectively, horizontal, direct-acting, single piston-rod. The trunk engines were 60 horse-power collectively; these two examples were adapted for the screw. For paddle-wheels, the engines of the greatest power were a pair of 140 horse-power, of Belgian repute, the framing and paddle-centres being of wrought-iron, thus ensuring sufficient strength with a reduction of material and weight. To describe each engine in detail would be tedious, as well as of little value to the engineer of the present day. Allusion to the defects and improvements will be found under the different descriptions of the necessary appendages.

I will now proceed with a brief notice of the marine engines exhibited in the year 1862, when it will be seen that a great improvement had taken place between the two dates alluded to. We are, I am happy to state, still making an advance, and I trust to be able, in the course of this paper, to describe these improvements; but, at the same time, I beg to suggest that there is plenty of room for further improvement in the detail of marine engines, which, doubtless, will be ere long taken into consideration by those interested in these matters.

In the year 1862, the International Exhibition was again held, and with much success as far as regards marine engines. The class exhibited showed a great improvement, both in design and arrangement. The oscillating engines adapted for the paddle-wheel did not exhibit much alteration, although it cannot but be said that in detail a change for the better was perceptible. With reference to the engine adapted for the screw, a complete revolution had taken place since the Exhibition of 1851. Valves and gear were altered, starting gear simplified; positions of condensers, air pumps and valves, in a much more correct state; number of details lessened; and, in fact, the entire arrangement fast approaching to a nearer state of perfection, viz., accessibility to all the parts in action without disarrangement. The following is a brief account of the writer's observation of the class of marine engines exhibited:—The paddle-engines were vertical and inclined, oscillating, of the ordinary type and arrangement. The valve gear was of two kinds; the counter-balanced eccentric, and the ordinary link motion. The air pumps were worked by eccentrics in some instances, and in others by cranks. The mode of starting was by the ordinary ratchet or wheel and pinion; the bilge and feed pumps were in some cases worked by the oscillation of the cylinder, and in others by separate eccentrics. The means for disconnecting were of the disc and the drag-link kinds. Paddle-wheels were exhibited with fixed and feathering floats. Five examples of oscillating engines were exhibited, including models and drawings. The engines for the screw propeller were as follows:—One pair of double trunk engines, having injection condensers, with an improved arrangement of air-pumps and valves. The double piston-rod return connecting-rod type was well represented; this arrangement is used on account of the great length of stroke and connecting-rod attainable in a given space. In the Exhibition now alluded to there were six pairs of engines of this class, with injection condensers and air-pumps of the ordinary arrangement, and one pair of engines with the improved arrangement of condensers, pumps, and valves. The single piston type of engine was not largely represented; one pair with the improved injection condenser, pumps, and valves, and one with those of the ordinary kind. The single trunk arrangement was represented by one pair, with single-acting trunk air-pumps in the condensers. The air-pump trunk with double piston-rods return connecting-rod engine was shown by drawings only. Vertical direct-acting engines were represented thus—one pair with annular cylinders, double piston-rods, and injection condensers of the ordinary kind; one pair with single piston-rods and surface condensers; and another pair as the last, with ordinary condensers.

It will be understood that in the previous examples the cylinders were arranged in pairs, the cranks being at right angles. In order to obviate the strains imposed at the extremity of each stroke, one firm exhibited engines with three cylinders, with spur gearing for reversing, stopping, &c., which were termed the expansive and economical principle. Lastly, I allude to the writer's invention "Burgh and Cowan's patent antifriction trunk engine," so arranged, that the friction of the trunks is dispensed with, and no area lost in the cylinder. This arrangement was represented by a pair of engines and drawings. Having thus briefly alluded to the marine engines exhibited in the two International Exhibitions of 1851 and 1862, I will now proceed to give a detailed description of each portion.

The arrangement of marine engines in the hold of the ship is, perhaps, not generally thought to be of so much importance as it really is. It should be strictly understood that the attention required for engines of river steamers bears no comparison with that required for marine engines; imagine a ship in a gale, and heated bearings, and a faint idea can be formed of the duties required, and the reason for a free access to all the working parts.

For the purpose of illustration to those readers who are not professional engineers, I will briefly specify what the necessary component parts of a pair of marine engines of the present day consist of—viz., cylinders, pistons, slide valves, piston rods, slide casings, expansion valves, blow-through valves, piston rod guides, connecting rods, cross-heads, main frames, crank-shaft, eccentrics, rods, links, valve rods, guides, condensers, air-pumps and valves, injection valves, shifting valves, discharge valves, bilge and feed pumps, valves for the same, starting gear and turning gear, lubricators, and all the necessary levers, bolts, nuts, &c. It will thus be seen that marine engineers have more difficulties to contend with than is generally known. To understand the use and real character of each of the above details is not the work of weeks or months, but years. It should not be forgotten either, that the honour of our nation, and the lives of its representatives, are often in the hands of the marine engineer. I will now proceed with the descriptive illustration of details, showing defects, improvements, and suggestions for the future, commencing with slide valves.

These valves govern the entrée and exhaust of the steam to and from the cylinders. Two kinds or classes of valves are now universally used, the common and the equilibrium; the former is so well known that a description of it is scarcely necessary. I will only observe that its use for larger engines is much on the decrease, on account of the stroke of the valve being due to its outside lap, which for large ports is considerable. Equilibrium valves are so called from the equal action of the steam tending to lift the valve from, as well as to press it on its facing. These valves are double-ported to reduce the stroke. One firm has lately introduced three-ported valves, to still further reduce the stroke. In order to reduce the friction of the valves on the facings, rings are used encircling the body of the valve, adjustment being gained by screws, ratchets, and springs to prevent looseness. In some cases a communication from the back of the valve to the condenser is arranged, to still further reduce the pressure on the valve facing. Slide rods are usually one to each valve, but latterly two have been introduced for large valves, which no doubt greatly assist in guiding the valve during its action.

The next portion in rotation will be that for working, reversing, and stopping the action of the slide valve, universally known as the "valve-link motion." The date of the origin of this motion is doubtful. Mr. Zerah Colburn, in his new work on locomotive engineering, tells us, however, that 1832 is the earliest period of its application for locomotives. Marine engineers introduced it

* Paper read before the Society of Arts.

firstly for oscillating paddle-wheel engines; afterwards for fixed, horizontal, and vertical engines adapted for the screw propeller. The object of the link motion is to reverse the action of the slide valve without disconnection. The links now in use are of two kinds, slotted and solid. The slotted link has the sliding block within it, whereas that of the solid kind slides within the block. The means adopted for raising and lowering the link are various. One maker prefers to use a lever, secured on a weigh-shaft, passing over the front part of the cylinders, motion being given by a worm and wheel, the former being keyed on or forming part of the starting wheel shaft. Another firm deems it better to impart motion to the lever by a ratchet and pinions. A third authority raises and lowers the link by a rod connected to a block surrounding a coarsely-pitched screw, motion being given to the screw by mitre gearing; whilst another firm prefers to fix the block, with the screw to be elevated and lowered. These two last are undoubtedly the most powerful of the examples given.

The systems at present adopted for guiding the slide valve rod are of three kinds. First, the dove-tailed guide, similar to that used by tool-makers for the arm of a shaping machine. Secondly, a block of gun metal sliding on two fixed turned rods as guides over and under the valve rod. Thirdly, the valve rod secured to a square bar, working in a bracket, and cap to correspond. This last may be said to be the most simple, but perhaps not so rigid as the first example. The double guides are complicated, but at the same time produce the rigid resistance to the strains imposed on the valve rod by the vibration of the link.

Some makers of marine engines prefer to allow the link to rest or hang on the block pin, inserted in the lever of the slide rod weigh-shaft. Such a practice dispenses with guides. Excessive vibration of the link on or in its block greatly deteriorates the action of the valve, it being understood that, whilst the link has an ascending or descending motion, as well as sliding, the strain on the valve rod is increased, and at the same time the stroke is affected. The excess of the vibratory motion is painfully perceptible in the ordinary slotted link; the eccentric rods being connected beyond the block pin, a direct action cannot ensue. The distance between the centres of the eccentric rods and block regulates the amount of indirect action. Links of this kind are often hung from a rod connected in the centre to the link, either to the clip or at the back. This is far better than at the lower end, as the connection of the suspension rod regulates the ascending and descending motion of the link whilst at work. The link resting on the block, when for going ahead, obviates to a certain extent some of the evils alluded to. The gain by the introduction of the solid link, with the eccentric rods connected at its extremities, is strength with less material, but the vibrating motion is not decreased. In order to obtain a more direct, and if possible a perfect action, the eccentric rods have been secured to the link, so that the centre of connection may be on that of the block, and by this the vibratory motion is effectually got rid of. There have been two distinct modes for accomplishing this, which I have had the opportunity of observing. The first example is, two solid links, one on each side of tho block, the eccentric rods being connected to pins on the outer face of each link, the inner face and sides being sustained in a groove in the block, which oscillates on its axis in the eye of the valve rod, the links being one on each side. The second example is like the first in principle, but one solid link only is used, of a dove-tailed form in section at the inner face, to prevent the link from slipping out of the groove in the inner block; the eccentric pins are fixed in the extremities of the link, and the rods are attached as in the last example, but with a single eye. The writer has designed a solid link and connection, which, although not superior in principle of action to the two last examples, is more simple in construction, and has less working portions; therefore it may be held to be worthy of introduction. A solid bar of iron is slotted at each end, to receive the single eye of each eccentric rod, so that the entire surface of the link remains unbroken; it is secured in a block with an adjusting portion and key at the back, the front being open sufficiently to admit of the ascent and descent of the eccentric rods; adjustment in front can be attained by loose portions and set-screws, but this last is not imperative, as the wear of the link and block is very slight when the acting eccentric rod is on the centre of the block; the block has provisions on each side for suspension, the valve rod having portions formed to receive the block; the back part of the rod works in a dove-tailed guide of the ordinary kind.

It now becomes necessary to treat of the suspension or lifting rods for solid links; for this a few words will suffice. As the ascent and descent of the link whilst in motion are governed by the length and position of the rod, it is almost needless to state that the suspension rod should be connected in the centre of the connection of the eccentric rod. The link, when for going a-head, should be down. It may now be argued that the vibration of the link, when for going astern, must be excessive. Granted; but as the forward motion of the ship is of the most importance, it is not unfavourable to economy to adopt the connection alluded to. In some cases the solid link is guided at the top or bottom, but this is only required when an overhanging or outside connection of the eccentric rods is resorted to.

The next portion for consideration is the expansion valve and gear; the use of this valve is to allow the steam to be cut off at the early or given part of the stroke of the piston, and the expansion or elasticity of the steam completes the power required. Now it is certain the use of high-pressure steam for large cylinders and short strokes, produces excessive shocks at the commencement of the strokes and thereby entails an increase of strength in the materials used, so that the proportions are larger than for ordinary purposes. It is clear also that, when steam is admitted at an excessive pressure against the piston suddenly, it (the piston) receives an impetus equivalent to the power imposed; and in no case whatever could an engine of proportions for low-pressure resist the strains imposed by the use of high-pressure steam. The ordinary pressure adopted by marine engineers is from 20 to 30 lb. per square inch, more often the former than the latter. I am not aware, however, of any cause why 60 to 80 lb. should not be adopted, with a great increase of economy and power. Of course the present proportions of engines and boilers would have to be increased if the same materials were used, but steel boilers, shafts, and rods might be introduced with considerable advantage, embracing great strength with less weight.

Having alluded to the ordinary pressures at present used, it will be well now to advert to the expansion valves. These valves are of three kinds, throttle, slide, and tubular.

The motions imparted to the throttle valve are oscillating and revolving, the latter is now most generally adopted, but with this disadvantage, that the action is equal both for supplying and cutting off.

The slide valves are of the ordinary and gridiron type, the latter may be said to be the better, on account of the stroke being so short in comparison to that of the former.

Tubular valves are tubes inserted in each other, with ports to correspond, a sliding or rotary motion accomplishing the desired effect. The motions imparted to these several valves are generally uniform, either by mitre gearing or eccentrics, consequently the action of the valves is not perfect. The proper motion for an expansion valve is to open gradually and close suddenly; to obtain this the old but correctly working cam must be resorted to; this useful arrangement is too often discarded to make place for newer but less correct productions. It may of course be urged that the cam is not applicable for high velocities, but undoubtedly its use might be attained by introducing stiff gear and perfect equilibrium double-beat valves; by dividing this valve centrally a more correct action can be attained, in relation to that of the steam, on the valve whilst closed and open. The merits and demerits of the expansion valves here alluded to are almost equal. The ordinary throttle-valve has less friction than any yet introduced, but it possesses the great evil of throttling the steam when closing; also when this valve is worked by levers, or has a vibratory motion, should the stroke be lessened, the full area cannot be attained. The last evil is dispensed with in the remaining example, as the ports or openings are much larger than required when the valve is at full stroke, and not too small when the least motion is given. The friction of the gridiron valve is perhaps in excess of the other examples, as in the case of the tubular valves the action of the steam is neutralised. The means adopted for altering the grades of expansion valves whilst in motion are various. A spiral motion is the one universally adopted, and there is not the least doubt it is correct.

I will now call attention to the following description of an expansion valve and gear which I have designed for high velocities:—A cylindrical casing has within it projections at given positions; two of these projections act as spaces between the ports of ordinary tubular valves. The valve now explained is tubular, but the area centrally is half of that of the ends, which are parallel for given lengths, due to the stroke of the valve. These parallel lengths also regulate the neutrality of the valve whilst in action. At the present time the means adopted to impart the motion is a disc of metal with a circular slot; within this slot is a brass nut into which is screwed a pin. The connecting rod of the valve is attached to the pin in the ordinary manner. The means for altering the grades of expansion is by loosening the pin by its handle, and allowing the nut to slide in the slot to the required position. It is almost needless to add that the steam enters at the side of the casing, and escapes around and through the valve, keeping it in equilibrium.

The valves next in requisition are those for the ends of the cylinder, commonly known as relief valves. The usual kinds adopted are discs, with springs or weights to resist the given pressure of the steam. The action of these valves is, of course, due to the excess of pressure within the cylinder over that of the resistance caused by the springs or weights. It has been proved that in the case of excessive priming of the boilers the cylinders are suddenly flooded; in order to release the water, cocks are sometimes used, but in many instances the springs or weights are lifted by levers. Now in the case of cocks, if not provided with valves beyond them, they must be worked by hand at each return stroke of the engine, or the vacuum will be destroyed. The spring valves will close naturally, or by the spring on its release from the hand lever. High-pressure steam has been lately introduced, with great advantage, in the place of springs, but with an entirely differently arranged valve and casing.

I have arranged a relief valve, so that the spring is not tampered with by levers or hand power, and an instantaneous opening can be effected without cocks, &c. The spring valve has an opening in it centrally, to receive on its outer side a flat disc, termed the vacuum valve. On the inner side is a provision mitred to receive a solid disc valve, which, on being pressed inwards by a spindle and lever, allows a free exit for the steam and water; on a vacuum being caused, the vacuum valve, which is guided on the spindle alluded to, closes the opening air-tight; by this it will be understood that the spring has not been in requisition, but on closing the inner disc the spring valve becomes one of the ordinary kind. Previously to starting the engines it is well known a vacuum should be caused in the condensers, also the cylinders and slide casings should be warmed, and the condensed water be allowed to escape through the relief valves or cocks.

The valves used for the purpose alluded to are termed the "blow-through valves." It may be here observed that, in some cases, the ordinary plug cock is preferred for this purpose. When valves are introduced, they are generally of the ordinary disc kind, but one firm adopts a common slide valve for the purpose, with the advantage of simplicity of levers, &c., and easy manipulation.

The piston rods of marine engines are subject to excessive strain, consequently the use of guides is imperative. For the single piston-rod engine, the universal system is a channel underneath the rod, the guide-block being generally of gun-metal, and the upper portion attached to the piston-rod by bolts and nuts. For double piston-rod engines the guides are of two kinds, the first arrangement is as the last, and the second, as for high pressure engines or double guides. To say which is the preferable mode of arrangement of guides will, perhaps, be deemed bold, but I may venture to state that I deem that for the single piston-rod the best of any yet introduced.

I cannot close this portion of the present paper without alluding to the admirable arrangement for tightening the gland of the piston-rod stuffing-boxes, introduced by the firm of Messrs. Maudslay, Sons, and Field. The screws are of the ordinary kind, but, in the place of nuts, worm-wheels are used, worms being fitted to correspond; and motion can be given by a box-spanner while the engines are at work. This is one of the most important improvements tending to accelerate the progress of a ship during a voyage of, say three or four months. Imagine the engines requiring stoppage during a gale in order to tighten the glands, and a fair estimation can be formed of the value of the improvement alluded to.

Having commented, though somewhat briefly, on the cylinder appendages, attention may now be given to the main frames and crank-shaft. The main frames may be said to undergo a continuous strain, and must, consequently, be of a certain strength in order to preserve the requisite rigidity. The cylinder is attached to the one end, and the condenser at the other, whilst the crank-shaft has to be supported in its bearings. Not many years ago a celebrated firm used to make the condenser and main frame in one casting; since that we have had the well-known frame, like the letter A laid on its side, also the hollow frame, with a raised projection for the crank-shaft, and a stay from the upper portion connected to the cylinder; this last may be said to be the most simple, and, at the same time, of less material than the A frame. As before stated, the strains on the frames are continuous, yet, when sudden shocks occur, from the racing of the engines or the priming of the boilers, the tenacity of the cast-iron is severely tested. As this is the case, wrought-iron might be used with great advantage, both as to increase of strength and decrease of weight. The crank-shafts of marine engines are generally of wrought-iron, in one mass, the cranks being double, and forged with the shafts. Three bearings are deemed imperative, so as to equally distribute the strains. Now, this is correct in theory and practice, and the writer will be deemed committing a grave error no doubt in mathematics, when he assumes that the forward frame and half-crank can be dispensed with, in order to reduce the weight and material. He is, of course, aware that the thrust and pull of the connecting-rod will be thrown on the centre crank and bearing, but, in order to counteract this, the length and diameter of the shaft at that part should be increased. He would also prefer, in this case, to extend the frame and connect the upper portion to the condenser; the cap being on the top instead of at the end, as now used. Screws might be employed to adjust the side brasses; the eccentrics could be within the cranks, or between them and the bearings.

Having alluded to the principal working details, I will now lay before you a description of the mode of condensation—past and present. It is well-known that the principle of condensation is to convert the steam into its original state. The contact of the cool fluid, in the shape of water, accomplishes this in the ordinary condenser, and cooling surfaces in the surface condenser.

In the days of the introduction of side lever engines, the arrangement of the condenser and air-pump was faulty; in some cases the foot-valves were almost inaccessible. Not many years ago, being on board a steam-ship fitted with old side lever engines, which were then undergoing repair, I noticed a rope and block tackle over near the condenser. On inquiring of the engineer how he progressed, the answer was, "I am just going to sling one of the men with this tackle, by the heels, to inspect the foot-valves; and that," said he, "is no foolish job." On further examining the engines, I found that an upside-down attitude was required, and indeed the only one allowed for the inspection of the valves in question. Happily now, however, such an inconvenient arrangement is of rare occurrence. We also find the side lever engine is being superseded by that of the oscillating type.

The arrangement of the ordinary condenser and air-pump for oscillating paddle-engines is generally as follows: the condenser is situated between and below the trunnions of the two cylinders; the air-pumps are at an angle, with trunks and connecting rods of the ordinary kind; the foot valves are at the bottom of the barrel of the pump, the piston has valves in it; and the discharge-valve, when not at the top of the pump-barrel, is at its side. Now, the principal defects in this arrangement are in the position of the valves and condenser. When the foot-valves are directly underneath the pump's piston, it is obvious that an almost entire disconnection must be made to inspect them. Also, in the case of the piston-valves requiring inspection, the pump-cover must be removed, and to attain this the gland packing has to be slackened, and the connecting rod disengaged. Now, to avoid these evils, doors might be introduced, but with these disadvantages—increased height or length of the air-pump passages, and a body of water always above and below the piston, which undoubtedly is what any right-thinking engineer would disapprove of, it being clearly understood that an air-pump will produce a better vacuum when the piston thoroughly discharges the contents between the foot and delivery valves at each stroke.

Having thus pointed out the existing evils of the ordinary arrangement, it will not be deemed out of place to introduce a remedy. The condenser at the side of or below the pump is one of the worst positions that can be conceived; the idea of allowing the condensed steam to fall, only to be raised again, seems on consideration to be foreign to the ideas of our talented engineers. It is well known that, in ordinary arrangements, the condenser is always in the position alluded to; steam even of a low pressure is larger in volume, but not as dense and heavy as water; it is also more elastic, hence it will more readily ascend. This, then, being clearly understood, it is not unwise or impracticable to assume, that if the condenser were on the top of the air-pump, instead of at its side or bottom, a better vacuum would be maintained. I beg to offer a description of an arrangement of condenser and position of the valves, both for correct action and accessibility. It will be understood that the condenser in this case is over the air-pump; the suction-valves are inverted, consequently the weight of the water assists the action of the piston in causing a vacuum. The exhaust-steam from the cylinders rushes up the exhaust-pipe, and enters on the top of the condenser. The water in the air-pump is discharged through the delivery-valve, at the top of the pump, and from thence through the delivery-valve at the ship's side. A door is secured opposite the delivery-valve, and doors are provided on each side below the bottom of the condenser, for the double purpose of inspecting the suction-valves and the air-pump piston.

This arrangement of condenser and air-pump will occupy as little room as those of the ordinary kind, with the advantage of accessibility to all the working parts without disarrangement. It may be argued thah the stuffing-box, being in a recess when used for guides, would be troublesome to keep tight or repack, but if oil be always kept in the recess, so as to entirely cover the gland, it would tend to lessen the liability of leakage; the nuts of the gland and bolts could be adjusted by a box-spanner, or the bolts prolonged to the top of the condenser. In cases where the depth of the ship would admit, the recess could be dispensed with; trunks are not proposed for this arrangement, as their diameters would be necessarily increased, owing to the length required to pass through the condenser, unless a recess were resorted to as now proposed.

The next portion of the subject now before us is the ordinary condenser for screw engines. The action of the air-pump in this case is usually horizontal, consequently the valves are at right-angles to the pump. To describe each arrangement of condenser and air-pump that have come under the writer's notice would occupy too much time, consequently a brief mention of two or three examples on this occasion will be deemed sufficient. For direct-acting and trunk engines, with the cylinders secured together or side by side, the condensers were between, and in some instances in front or at the sides of, the air-pump. The foot and discharge valves were directly over each other, the former under the pump at each end, the condensed water or steam being drawn through the foot valves and forced through those above. In another instance the foot and delivery valves were extended the entire length of the air-pump and passages, the position of the valves over and under being as before, and the condenser being between the air-pumps. For return connecting-rod engines, the condenser and air-pumps are subject to great disadvantages. In order to obtain a passably good arrangement, and at the same time occupy a moderate space in proportion to those last mentioned, the condenser, &c. have to be shaped to suit the purpose required. It must be perfectly understood that when the piston rods are beyond the crank-shaft, as in the examples now in question, there is a certain amount of space required for the piston-rods and guides of the cross head or guide block, whichever may be used. It is also clear that accessibility to all the valves without disarrangement should be attained. To illustrate these desiderata, the following examples will be sufficient for the present purpose. In one instance the condenser is partially between the cylinders, and extending beyond the crank-shaft; the air-pumps are at the side of the condenser; the suction-valves extend the length of the air-pump, and the discharge-valves are between each pump, the pump and the valves being beyond the crank-shaft.

The next example is as follows:—The condenser and its appendages are entirely beyond the crank-shaft. The air pumps are at the extremity or sides and near the bottom of the condenser. The foot and discharge valves extend the entire length, and are arranged over and under the pumps in the usual form. The guides for the piston rods are between the upper portion of the condenser and that of the discharge chamber.

Having disposed of the principal arrangements of air-pumps and condensers as formerly constructed, allusion will now be made to those of recent improvement and practice. As before stated, a better vacuum can be attained when the condenser is over the air-pump instead of at the side. For direct-acting engines there are two arrangements specially worthy of notice. 1st. The air-pumps are worked by the steam-pistons between the cranks, as near the base lines of the engine as the periphery of the circles will admit, the condenser being one chamber directly over the air-pumps. The suction valves are inserted in the bottom of the condenser, so as to effectually drain the same. The discharge chamber extends the entire length on each side and back end of the condenser, the valves being nearly in the same line as those for the suction, but reverse in action. The next example is the same as the last in principle, although different in arrangement. The air-pumps are situated as in the last example, but the condensers are separate, one to each engine, over and on each side of the air-pump. The suction valves are inverted in the bottom of each condenser, to obtain the advantage before alluded to, the discharge chamber and valves being central or between each condenser, and directly over and between the air-pumps. It may now be argued, that if the two examples last mentioned are perfect in action and arrangement, what is the cause of the diversity? The answer to this is, diversity of idea. Engineers, as a rule, are averse to the act of copying from each other. No sentence grates more harshly on the ear of a scientific man than the words, "where did you copy this?" or is more repugnant to his dignity.

DESCRIPTION OF THE MADRAS RAILWAY.*

By T. H. Going.

In this paper my design is not to produce either a scientific or statistical essay on the Madras Railway, but to give such a general description of its leading features, physical and constructive, as an acquaintance of more than four years enables me to offer; trusting that, at least, the novelty of the subject may invest it with some interest to those who have had no personal experience of Indian engineering.

Madras was the latest of the three Indian presidencies in entering upon the construction of railways; the first having been inaugurated in the summer of 1853. This is now known as the South-west Line, and was originally commenced without any well-defined idea as to its ultimate direction, beyond a general one, that an easterly course was undesirable, owing to the presence of an ocean on that quarter; a direct northern one not offering many inducements, either as regards the richness of country or its physical adaptability. Why a southern start was not given to this first essay is not so easily explained, since in that direction lies a country of extreme fertility, thickly populated, and with everything to recommend it from an engineering point of view. There were, no doubt, reasons for this, as potent as those which swayed the judgment of the Government advisers, who, when they *had* selected the south-west route, were careful that such large towns as were linkable in the regular course of a railway should be scrupulously avoided; probably fearing, like the Sybarites of yore, lest the shrill notes of the steam-cock should disturb the peaceful slumbers of the inhabitants.

Thus treading its unsocial course along, the South-west Line at length reaches a point on the western coast known as Beypoor, where the terminal works are erected. Not that Beypoor can boast a harbour superior to any other river-mouth along the coast, for they all, more or less, share alike the natural effects of sand-bearing currents, which, checked by the action of the south-west monsoon, create a bar across their entrances. There is not a harbour along the west coast, from Cape Comorin to Bombay, which can afford security to vessels of any considerable tonnage, except, perhaps, Seedashaghur, where a barrier of coast islands might be so connected, by artificial means, as to constitute a good harbour, sheltered from the effects of this reflux of sand. Beypoor is in fact an open roadstead, and was probably selected for the terminus by the influence of the iron company, whom the existence of extensive beds of rich hematite in this locality called into being some years back, and whose works, now in a semi-ruinous condition, stand as a costly proof that in the absence of a local supply of fuel the manufacture of iron is not a profitable speculation. Yet, should the screw-pile pier, at present in course of erection at Madras, prove a success, no doubt its adoption at Beypoor would follow; and it is impossible to overestimate the advantages, both social and political, which would result from the connexion by rail of two efficient harbours, one on the west, the other on the east coast of the peninsula.

For many miles after leaving Madras the line traverses a flat country of no great geological interest. Everywhere beneath the

* From the Transactions of the Institution of Civil Engineers of Ireland.

soil the great underlying stratum is decomposed granite, which becomes more and more consistent in proportion to the depth,—as may be readily observed in the deep wells for irrigation purposes, so frequent in Indian cultivation,—till it finally merges into solid rock, yielding only to the quarryman's art. These sections would lead one at once to conclude, from the texture of the material and veins of chloride, quartz, &c., which they display, that this decomposed stratum is the result of decay gradually advancing downwards with the lapse of time, and do not anywhere indicate the character of drift.

When undulations of the surface of the ground necessitate railway cuttings it is generally found that the nucleus of the cutting is the ridge of a greenstone dyke, of which the upper portion is more or less decomposed. It may be supposed that in a country of this character, clays, valuable for pottery uses, will be encountered, as indeed is the case; and the railway cuttings have laid bare some fine deposits of cayolin and other clays, which are turned to useful account in the school of arts at Madras. Further west, near the Poiney river, gneiss rocks begin to show, diversified by numerous trap-dykes and granite veins of all sizes. This character continues till within a few miles of Salem, where the line cuts a bit of ground intersected by veins of carbonate of magnesia, the so-called "Chalk hills." Near Sunkerry Droog, and again near Coimbatore, it crosses some not very extensive bands of metamorphic limestone. Some of the officers of Dr. Oldham's staff are now (June 1862) engaged upon the geology of this part of the country; and, up to the present time, they have not met with either the carboniferous limestone or dolomite, nor has a single fossil been ever found in this region. It has not, however, been properly examined as yet. Further south, in the Trichinopoly district, they have made a splendid collection of fossils from the carboniferous limestone, which now adorn the Geological Museum of Calcutta.

The great geological feature along the eastern part of the line is the magnetic iron hill near Salem, close to the southern slope of which the line runs for about six miles. The ore from this hill supplies the Porto Novo Iron Company.

The next remarkable feature in the geology of the railway, as we proceed westward, occurs after crossing the Cauvery river, and approaching the foot of the great triangular spur of the western ghauts, known as the Neilgherry hills, round the southern skirt of which the line curves towards the west coast. These hills are a solid mass of gneiss, cut up with dykes in all directions; and the railway through that district has the same tough substance to encounter in many of its cuttings.

There is a peculiar deposit know as laterite, which occurs indiscriminately in all parts of Southern India, and is probably not referable to any special geological period, but which reaches its greatest development on the western coast, where it may be seen composing the entire mass of hills, some hundreds of feet in height. It may be described as a gritty, porous clay, indurated by ferruginous infusion. It is massive and easily worked, though at the surface very hard for some inches in depth. It is used for building purposes in the place of bricks (as the derivation from the Latin might suggest), being cut out in blocks, which are further shaped by means of a hatchet. Of course, in a climate subject to frosts, the use of such a material in building would be out of the question; and even in India I do not think it can be considered as a material of sufficient durability for railway building, except it be for stations and small drains. It is also used as ballast.

From the foregoing remarks it is evident that there is no lack of good material for railway construction across the southern peninsula. Even throughout the plains of the Carnatic there are few localities in which a granite quarry, within tolerably accessible distance, may not be looked for. I am acquainted with instances where the mere stripping of the soil for a few inches of depth reveals the surface of a granite plane many acres in extent. I am not aware whether it may be considered as one of the characteristics of granite, that near its surface it is disposed in successive layers, analogous to the coats of an onion, or whether, when such a character is observed, it should not be rather attributed to the effects of aqueous deposit than the action of cooling. It is certain that the so-called granite of Madras presidency may be thus raised in successive layers of varying thickness, and hence I am doubtful whether it should not be regarded as gneiss.

Should, however, the more solid building material fail, there is always available on the plains an abundant supply of clay to make the brick—well-beloved of Indian engineers of the Public Works Department—well-beloved, too, of the mild Hindoo mason, whose scantily developed muscle somewhat shrinks from the rough practice in stone, so hard, so heavy, so incapable of a sly-face finish, to smooth over any inherent defects. Famous bricks, too, have been made in India since railways have introduced English Civil Engineers. For Government works the bricks are usually but half-burnt; and to smother up bad work, it is the custom to finish off with a handsome coat of plaster. It is not to be wondered at if bridges thus constructed resolve themselves into their original elements—it may be the first, or it may be the second moonsoon of their existence. Indeed, the first essay in all Government bridges would seem, as a general rule, to be merely regarded as an experiment. Bridge No. 2, constructed on the ruins of the former, will probably be better adapted to the requirements of the locality, and, perhaps, more carefully built, should it be within easy access of the engineer of the district; but since his professional supervision may extend over an area of country as large as the principality of Wales, it is more likely that a native maistry will have the management of the re-erection, and that he will put up a second bridge the counterpart of No. 1. This is no exaggerated picture of the manner in which the public money is squandered in Indian government works.

The mode of quarrying granite in the Madras presidency is peculiar, and a description of it may be interesting to those unacquainted with the process. There is in India a caste of people know as wudders, whom I may, in general terms, describe as the navvies of India. They are of two classes—those who work in stone, and those skilled in the manipulation of earth. The stone wudder is a hardy, sinewy fellow, whose stock in trade consists of a house, which, when on his travels, he transports on the back of his donkey, or else on the head of his wife (no remarkable instance of tyranny, since it consists of nothing but a mat and a few bamboo stays); then he has a heavy crowbar, a few iron wedges, some earthen pots, a dog, and a small stock of rice. He is, in fact, a being a good deal resembling the Irish tinker, of times not so ancient but that we can recall the picture. Arrived at his quarry, his first care is to lay in a stock of firewood, which he cuts in the jungle, and removes by means of a peculiar bandy or cart with low wheels of solid timber, drawn by a pair of buffaloes—an important part of his equipment, which I omitted to include before in the list. The wood is piled in small quantites on the surface of the rock, and ignited, usually during the night, their favourite time for work. After the fire has been steadily kept up for some hours, the upper layer of the rock expands sufficiently to produce a separation from the substratum. The separation is accompanied by a dull bursting sound; and the extent of the severance is ascertained by a series of taps with the crowbar, the response of which is conclusive to a practised ear. The next operation is to break up this loosened bed of rock into fragments of a size convenient for handling, and this is effected by means of a round boulder of greenstone, as large as can be lifted to his head with the assistance of another man. This he dashes down with all his might on the rock, and sometimes succeeds in making a fracture with a single throw; but it often requires to be repeated many times; and it is wonderful, considering the clumsiness of the method, with what success he turns out handsome square blocks of stone, of dimensions well suited for building. This, however, is more to be attributed to the natural tendency of the stone to square fracture, than to the skill of the wudder.

The earthwork of Indian railways is performed by a different process from that usual in England, where the quantities in cuttings and embankments are commonly so proportioned that the material taken out of the former may be sufficient to construct the latter. In India, however, the value of human labour is low—a man's wages on the Madras railway being equal to 3*d.* per day, and a woman's to 1½*d.*—the value of land is also small; and for these two reasons the system adopted is, to spoil the cuttings and make the embankments from side ditches. The use of wheelbarrows too is ignored, their representative being a flat withe basket, holding about two cubic feet. These are filled by means of an implement called a mommoty, which may be described as a large hoe with a short handle, and, being lifted on to the heads of the women, are by them carried to the bank. It is surprising how fast this process raises a pile of earth. The worst of it is, that a bank made in so loose a manner is liable to settle for a long time. It has been often attempted to introduce the wheelbarrow mode of work, but with little success. The basket of antiquity—probably antediluvian—still holds it own. I have heard of an instance of an enthusiast in wheelbarrows, who, having exhausted his morning energy in in the fond endeavour to reclaim a gang of coolies from the use of the objectionable basket, had the mortification, on making his evening tour of inspection, to find them carrying the wheelbarrows on their heads, in the belief that it was only a convenient modification of the principle. The greater part of the earthwork in Madras presidency, on the railway, in tanks, &c., is done by people of the same caste as the stone wudders whom I have described; and these people always perform their work by contract.

In speaking of the materials for construction, a few remarks on lime will be proper. I have alluded to the slight development of limestone in the Salem district; but for burning purposes the concretionary carbonate of lime common through Madras is most used. In this form it occurs in beds of varying thickness, as well as disseminated through the soil and over the surface of the ground. The nodules are of various sizes, from that of a pumpkin down to the bulk of a pea. A very common variety is shaped like the ginger root, and this I have always found to possess slightly hydraulic properties. In the neighbourhood of Madras, as well as on the west coast, almost the only kind of lime used is procured from the burning of shells found in beds a little below the surface, in low lands near the sea coast. The lime made from these shells, being very fine and white, is admirably suited for plaster, and is susceptible of a high polish, which is administered during the period of its setting by means of a smooth stone or crystal, rubbed assiduously over the surface so so long as any dampness remains, a little of the powder of soapstone being sprinkled on to assist the polish. Most of the public buildings as well as the private dwellings in Madras are finished in this way; and when the work is new it gives the effect of white marble. The action of the atmosphere, however, soon tarnishes the exterior of buildings thus finished, and they look shabby enough after three or four seasons; but the interior preserves its beautiful purity of appearance.

The Teloogoo name for lime is chunamboo, by which the various kinds of carbonate of lime known in India are designated. When calcined it is still called chunam; and even after the combination of the resulting oxide with water and sand has converted it into what in England we call mortar, the universal name, "chunam," is its only designation. In the calcined state, chunam is much used by the natives as a masticatory, being rubbed on the leaf of the betel vine, which is then folded up and chewed, the juice being swallowed. It may be in place to observe, while speaking of lime, that that used for building purposes in Ceylon is all produced from the calcination of coral. Indeed, on the coast, the buildings are mostly constructed of coral blocks, cemented by mortar of lime made from coral.

The average annual fall of rain in Madras, on the eastern side of the peninsula, is about 50 inches, but as much as 80 inches have been registered as the fall for three several years since the commencement of the century. Within a single month the rain gauge has indicated a fall of 42 inches, and on the 25th October, 1857, 12 inches of rain descended from the clouds in a steady pour of 12 hours' duration. From these data it will be understood that the question of drainage is one of some importance in the construction of a railway across such a country. The rivers, indeed, constitute the principal difficulties to be overcome, all the more so from the fact that being, during the greater part of the year, little more than broad shallow channels of sand, the great proportion of their duty is concentrated into the short space of a few weeks, during which the rains of the north-east monsoon descend. Those of the west coast must however be excepted from this general description, because the cloud-barrier of the western ghauts, whilst arresting the eastward progress of the south-west monsoon, pours back its deluge of waters to the ocean which washes the shores of Malabar; so that while this vapoury region monopolises all the waters of that monsoon which comes laden with the moist breath of the Indian ocean, the Coromandel coast must content itself with such watery stores as are picked up by the north-east monsoon in his shorter flight over the bay of Bengal. A corresponding difference of climate accordingly characterises the country on the two sides of the western ghauts. Innocent of water as these sandy channels of the east appear, however, when the question arises of laying the foundations of a bridge, this uncompromising element is found but to lie dormant within a few inches of the surface of the sand.

Various means of sinking foundations are resorted to by Indian engineers; a favourite one is that by wells. Thus, over the site of the pier or abutment are built a series of brick wells, about 3 feet interior diameter. They are placed side by side, and in sufficient number to cover the area of the foundation. Being built to the height of 3 or 4 feet, a diver gets into the well, and commences excavating the sand beneath his feet, and hands it out in a basket. As he excavates, the well sinks; and when it reaches nearly to the surface of the water, additional courses of brick are built up; and so on successively as the well sinks, the diver being obliged to fill his basket under water when the process of sinking has brought him beyond his depth. Finally a second diver stands on his shoulders to assist his descent. The wells being sufficiently sunk, the intervals and spaces contained between contiguous wells are filled with broken bricks mixed with stiff clay to within a few feet of the surface, and rammed hard. The tops of the wells are then removed to the level of this rammed surface, and as soon as the water has been reduced by the means of baling-baskets, the first courses of the foundaare laid with brick cubes, previously got ready by cementing together in this form a number of ordinary sized bricks. By means of these cubes the work is rapidly carried above the water level, and from this point, or perhaps a little below it, the ordinary brickwork begins.

When the depth of sand is very great, and water difficult to overcome, this is a cheap mode of evading the necessity for cofferdams and pumps. Of its efficiency however, as practised in Madras presidency, I have some doubts, as it is not usual to sink the wells below 10 feet, and the scour of floods in the Indian rivers often reaches beyond this depth. In Bengal the same system is adopted, but they usually sink their wells till a hard bed is reached. The engineers of the Madras Railway have not taken kindly to this Indian mode of founding; and it has been only resorted to in a few instances. In laying the foundations of the granite bridge over the Naggery river, of thirteen 40-feet arches, on the north-west line of the Madras Railway, the resident engineer, Mr. Smart (who, by the way, was a student of the engineering school of Trinity College), adopted the method of curbs. I can describe the *modus operandi* for the first pier, having been present during the sinking process. The curb consisted of a strong teak frame 40 feet by 9 feet, divided by cross scantlings into five compartments of 4 feet square, and equidistant. The thickness of the curb from under side of beams to upper surface of planking was 2 feet. It was placed accurately above the site of the pier on the surface of the sand, and the masonry built to a height of 10 feet, making an entire height, including the frame of 12 feet, this being the depth of sand above the solid substratum as ascertained by a pricker. Cross walls partitioned the structure into 5 cells, corresponding to the compartments of the curb on which it was built, and every course of the upper 4 feet had layers of hoop-iron worked into it longitudinally. It was then ready for sinking, a process similar to that described for the wells, a diver being set at work in the bottom of each cell to remove the sand, and hand it up by lifts to the top, where it was discharged. The sinking too, was found to be greatly facilitated by keeping the sand well cleared away round the exterior. After being sunk some feet a crack appeared in the masonry, which alarmed the divers, and it was with difficulty they could be got to proceed with the work. The structure went down in sudden jerks of a few inches at a time, and was finally deposited on its resting-place below the sand within ten days from the commencement of the sinking; and though a few cracks showed in the masonry, it was of no practical consequence. The total cost of the curb, for materials and workmanship, was about 130 rupees, and the sinking cost 90 rupees; 220 rupees, or say £22. The cells were finally packed with stone, which was then grouted, and a level platform thus prepared for the superstructure. Such a mode of getting in foundations would of course be only practicable where the sand was free from boulders.

The principal rivers crossed by the south-west line are the Cortiliar, the Poiney, the Goriathum, the Palar, the Cauvery, the Thootha, and the Kuddulhoondy. It was originally contemplated to cross all these rivers by means of arches of masonry. A great improvement has however been introduced by the substitution in many cases of wrought-iron girders, whereby the number of costly and tedious pier foundations is diminished. The total length of the south-west line, from Madras to Beypoor, is 405 miles, and the summit height attained at Mooroor, near the foot of the Shervaroy range, 1500 feet above the level of the sea. At Coimbator, where it passes near the base of the

Neilgherry range, a second summit of 1301 feet above the sea is attained, and between these two intervenes the deep valley through which the rapid Cauvery washes its way southwards. This elevation of this, at the point of crossing above the sea level, is only 495 feet. The gradients are for the most part favourable, the maximum being 1 in 60, necessited in descending from the last-named summit towards the plains of Malabar.

I have hitherto only spoken of the south-west line of the Madras Railway—as being that for the construction of which the company was origianlly raised, and which is now nearest to completion. In August 1858, the Government entered into a further contract for the construction of the north-west line, which is designed to strike out from Madras in as direct a course as is expedient, towards Bombay, and form a junction with the railway from that town near Moodgul, in the territory known as the Raichoor Döab, lately restored to the Nizam of Hydrabad. Two branches, one to Bangalore, the other to Ootacamund, have also been sanctioned, but construction has only been commenced on the former, the object of these lines is to give ready access to two such important stations. Bangalore being the great military head quarters of the Madras presidency, and Ootacamund its sanitorium.

The railway of greatest imperial moment however in Southern India is the North-west Line. Anyone who will take up a map of India, and trace a pencil line from Madras, through Cuddapah, Gooty, Bellary, Sholapoor, and Poonah, to Bombay, will immediately recognise a route which, as affording the most direct communication between the seats of government of the two western presidencies, and passing through military stations of great importance, would naturally suggest to the rulers of the country the expediency of fitting it with a railway, so as to secure those strategical advantages, which, however such writers as M. Streubil may decry them, as tending to relax the energy and enthusiasm of the soldier, yet were proved to be eminently attendant on a railway system during the operations of Lord Clyde in suppressing the mutiny of 1857.

There are many other considerations too, which greatly enhance the importance of these trunk lines to India. Prominent among these might be mentioned the great reduction of troops which would be rendered possible under the improved means of transportation; the exemption for European soldiers from those long fatiguing marches which, under an Indian sun, are so disastrous in their effects, the reduction of the enormous camp equipage; the carriage of troops at an extremely low fare, and of the mail without charge, as provided for under the system of Government guarantee, besides many other desiderata in the economy of governing. But these questions are not within the scope of my subject. It must, however, be a matter of surprise to those who can appreciate the advantages accruing from railways, that the Government of India should not strain every nerve to effect a speedy completion of the north-west line, instead of checking its progress, as they have recently done, through mistaken notions of economy.

On this line the bridges again constitute the chief engineering difficulties. There are twelve principal rivers to cross; among which the largest are the Naggery, Cheyair, Paupugnee, Chittravutty, Penair, Hugry, and Toongahudra; the channel of the Cheyair being some 60 chains across, and the others varying from 10 to 40 chains, making an aggregate of bridging over these twelve rivers alone of more than 3 miles in length. The designs are principally for masonry, piers, and superstructure of wrought-iron girders in spans of 60 feet, adapted for a single line of rails. The cuttings and embankments, too, of the Madras railway are, I may observe, all adapted for single line, the masonry being constructed for a double line.

The total length of the north-west line, to its junction with that from Bombay, is 330 miles. Two ranges of hills are crossed; the first at Ballapilly, involving a heavy cutting through quartzite, and a gradient of 1 in 60. For about 130 miles the earthwork is tolerably heavy; but to the north of Cuddapah the great plains of black cotton soil prevail, and the earthwork will consequently be light. The permanent way is formed of 75-lb. rails and cast-iron sleepers, with tie bars. The gauge is 5½ ft.—the standard for Indian railways.

The south-west line was laid with sleepers of the country timber, and though some varieties of this are extremely hard and tough, yet experience proves that there is no timber capable of withstanding the ravages of the white ant, or the effects of dry rot in this climate. Teak is the only timber whose use in sleepers has been attended with partial success. Even the English oak treenail becomes converted into a brittle substance, resembling charcoal, after little more than a year's exposure to the weather. The renewal of such a road is very costly; and in all cases of renewal on the south-west line, the cast-iron sleeper is being now substituted for the timber one. The first 96 miles of the south-west line open on the east coast, have cost for construction, including permanent way and rolling stock, £8500 per mile. The north-west line, so far as at present constructed, with a permanent way of much greater original expense, has cost only £7000 per mile.

The public works executed in India have long been conducted under the authority of a special department of Government, the engineers being, for the most part, supplied from among such of the officers of the army as are able and willing to submit to the slight preliminary ordeal required to fit them for the service. The greater number are selected from among the engineer corps and the artillery; their subordinates chiefly from among the ranks of the sappers and miners and the artillery; and the lower grades are made up from the native community. The labour is performed by coolies working for daily wages, occasionally by means of convicts, and in some instances small contracts are entered into.

In imitation of this organisation of the public works department, some of the Indian railway companies have adopted what is called the departmental system, under which the work is executed without the intervention of contractors, whose duties, in addition to their professional ones, the company's engineers undertake to perform. A good deal may be said in favour of this mode of working in the early stages of railway construction in India, where, owing to the character of the climate, want of local experience, and other causes, it might be difficult to find English contractors willing to enter upon such a speculation. Besides, it may be urged that, if the company can perform by their own officers the work usually committed to the agency of contractors, is it not a clear saving of the per-centage which the latter would calculate on in return for their labour and outlay? This looks true enough; and, under certain favourable conditions, would undoubtedly follow. These conditions, involving as they do, for the most part, questions connected with the general management of the company's affairs, are not suitable for discussion here.

There is, however, another important condition to its success which may be alluded to. It is, that the engineer should not have a larger amount of work placed under his charge than he can do justice to. In India, where skilled labour is scarce and of an inferior order, efficient overseers extremely difficult to procure, and dishonesty and peculation universal, an extraordinary amount of energetic supervision is incumbent upon an engineer, who, placed upon a district so organised, would do his duty conscientiously.

The length of the line under construction, committed to the charge of an engineer on the Madras railway, ranges from 20 to 25 miles. It is true that with an efficient staff of subordinates it would be quite possible for him to perform the duties of field and office, even with all the accessory functions of providing work-people, apportioning, managing, and paying them, preparing and distributing plant, keeping it in repair, teaching and training overseers, mechanics, &c., regulating a detailed system of accounts, guarding and disbursing immense amounts of the bulky silver currency, maintaining a harassing cross-fire of office correspondence, but above all, exercising that untiring vigilance over the work in progress which the apathy, carelessness, and deceit of the Hindoo workman renders so indispensable.

Subordinates capable of relieving the engineer of a portion of these labours are not, however, available in India, except to a very limited extent. On his own energy and bodily vigour, therefore, are mainly dependent the successful progress of his work—as many a zealous officer of the Madras railway has discovered at the expense of health. This, however, is an instance of the abuse of the departmental system. No practical person can doubt that, were the energies of the engineer limited to a distance of half the length (or say 10 miles) the cost of the work would vary in the same proportion, and its rate of progress and improved quality, inversely.

As railway construction progresses in India, the contract system of work becomes yearly more popular, though on a much smaller scale than that usual in other quarters of the world. Wealthy natives may be always found ready to undertake a limited amount of work by contract; they are, however, slow to embark capital, and have generally to be assisted with plant. Their ignorance of mechanical appliances is another bar against any very elaborate essays of this kind. This, indeed, is a disqualification which gradually diminishes as our workshops extend their practical lessons; and there is every reason to expect that native contractors will perform the greater portion of all future railway construction in India. I may mention that a company, composed entirely of natives, is at present raising a subscription to construct a line of 18 miles in length, from Arconum, the junction of the north-west and south-west lines of the Madras railway, to Conjeveram. Such an evidence of the beneficial tendency of the introduction of railways into India, towards developing the dormant capabilities of its people, must be as gratifying to the statesman as to the philanthropist.

THE MUNICIPAL ORGANISATION OF PARIS WITH REGARD TO PUBLIC WORKS.

By G. R. Burnell.

(Continued from page 96.)

The administration of the city funds is confided to a series of officers, who conduct their business with singular skill and attention to the public interests, though it must be confessed that they have allowed the spirit of red-tapeism, in the conduct of it, to gain the ascendancy; but these officers are not empowered to resist the will of the prefect if he should venture to step beyond the limits of his duty. They are only to discharge their functions; they have no deliberate voice, and they must carry into effect the orders that they receive from higher powers than their own. There is no kind of check upon the fancies or the caprices of the Prefect of Paris, in fact, and it cannot therefore be a matter of surprise that he should have been misled in many cases, and should have made the mistake of confounding straight streets with good lines of communication, and broad boulevards with efficient means of ventilation.

I fear that much of what has been lately executed in Paris, especially in the neighbourhood of the Madeleine and the Parc Monceaux, is liable to this reproach, and certainly it would have been long before the town would have been thus modified, if the municipal council had been freely chosen, or if it had correctly represented the wishes of the inhabitants. There is, moreover, this danger about the course that our neighbours have entered upon, that they have created a fictitious demand for labour of the highest and most dangerous class, which they must go on employing; and thus the necessity of always continuing the works at the expense of the town, is a constant source of preoccupation to them. The true remedy to this state of things, to the danger of the gradual increase of the debt of the city, and the creation of the fictitious demand for labour, would be, in my opinion, to restore to the municipal council some sort of control over the money of which they are supposed to regulate the application. It is to the facility with which the prefect can create a new debt, and the utter absence of control over his proceedings in this matter, that the danger of the present state of affairs in the city of Paris must be attributed.

In the meantime, the results of the system, in everything that relates to the maintenance of the public works and the comfort of the citizens, must be considered to be as nearly perfect as it is possible to make it. The streets are admirably kept, their surface is admirably paved, and their gutters are washed and swept twice a day, so that every kind of obstruction to the flow of water in the channels is removed with the least possible delay. The footpaths are not so well organised as the roadways, on account of the law which regulates them; but this branch of the municipal service is under a gradual system of change, and the consequences of this are very apparent in the state of the footpaths of the new streets and boulevards. The gas lighting is very well performed under the direction of the town authorities, and it is carried on with such an amount of luxury, in the district around the Louvre and Tuileries, that in the Rue de Rivoli there is a gas lamp at the distance of every fourteen feet, and in the courtyard of the new Louvre there is one every twenty feet apart; nor can this be considered exceptional, as there is the same profusion of light at the Bourse, at all the theatres, on the boulevards, the Place de l'Hotel de Ville, &c. The service des eaux et des égouts is very efficiently organised, and though Paris is still subject to the nuisance of the night-carts, it is so in a less degree than formerly, and, at any rate, the inhabitants of that city cannot reproach themselves with the pollution of the river by their excreta. The water supply to the town is conducted, at present, on a very confined scale, but much of the inconvenience thus created must be attributed to the conditions under which household property is held in France generally. The city of Paris is, however, energetically at work to cause the insufficiency of its present supply to cease, which desirable object it is calculated will take effect in the course of the next summer. It would not enter into my province to notice the superior decency and cleanliness that are to be observed in the streets of Paris, which form so marked a contrast with the sights and scenes that one is compelled to witness in London; but this must strike every beholder, and give him a higher idea of the municipal organisation of the former city. There are ample provisions made for the markets, the cattle and the wine trade (and the former of these is now to be shortly brought to the immediate neighbourhood of the town); the factories are under strict superintendence, and they are kept from becoming nuisances to the neighbourhood in which they may be placed—in fact, the municipal affairs of Paris are managed with a degree of skill that must excite our admiration, in spite of the facilities that are afforded by the system on which it is based for the indulgence of the æsthetical fancies of the prefect, or of a much more august personage. It is to be feared, as has been said, that these will lead the city to great expense, if some check be not soon placed upon them. Long lines of streets, and long avenues or boulevards, cannot be constructed without costing a great sum of money; and though it may be desirable to terminate every vista with a building surmounted by a dome, in the style that seems to be the fashion in Paris at present; yet the question of the cost of these improvements must rise up before the inquirer, and the consideration is forced upon him, whether the circumstances of the town were, or are, such as to render necessary so great an outlay as these domes, and the houses around them, must cost? That which we should do well to imitate in the French system is, the order that prevails in the organisation of their services for ensuring the fulfilment of the municipal duties; that which we ought to avoid is, the manner in which the Prefect of the Seine is allowed to dispose of the money of the taxpayers without any real control on their part of the funds so raised, or of the works that are undertaken avowedly for the public benefit. It may not be in the present day that the evil, which will inevitably attach itself to the exercise of the irresponsible power of the prefect, will be felt; it must however, sooner or later, entail such consequences as are fearful to contemplate. As long as the system of irresponsible government is confided to intelligent and conscientious men, there possibly may not ensue from it the results that are to be apprehended; but this is always a matter of chance, and the results that would attend the corrupt, or even the unintelligent, use of the power so given must be evident to any one that reasons upon the matter. At present there may be questions raised as to the necessity, or the usefulness, of some of the public improvements executed by the city of Paris; as to the consequences of the future development of the system, it is to me evident that they must result in the embarrassment of the city and the augmentation of the burdens upon the citizens. The very perfection of the organisation of, and the unity of system involved in, the services of the municipality, seem to me only to disguise the defects of the system of which they form part, for they will allow the working of it to proceed, till it will at length collapse by the debt in which the prefect, or his successor, will involve the town.

I have not thought it worth while in this notice of the municipal organisation of Paris, to describe the machinery that is put in motion for the purpose of making the inquiries into the expediency of declaring the works that the prefect may decide upon as being of the class that would come under the law of expropriation *pour cause d'utilité publique*, because the action of this machinery is very simple, and it is easily made to decide according to the wishes of those in power. The question of compensation for the property taken is in France, as in England, very much a matter of chance; that is to say it depends upon the skill with which the proprietor can make and support the claim that he may think proper to advance; for there is no rule by which the jury can fix the value of the land, or can ascertain the amount of the interest that may be attached to the properties or property under conditions that may escape observation. It is, however, the general impression that the compensation that has generally been given in the cases of the new streets and boulevards has been large, and ample for the purpose; so much so, in fact, that the proprietors of land and houses desire now to see the improvements carried on in their quarter, in the hopes of being expropriated in their turn. But this is in itself an evil, as the proprietors can only secure the high prices that they expect, on the condition of the public paying more for their property than it is worth; and the fact of some people getting more for their land does not compensate for the injustice that others may be exposed to. The system in France is nevertheless so closely like our own in its essential features, that I have not thought it necessary to direct your attention to it particularly. I have thought that the municipal organisation of Paris, with all its strength, and with all its weakness, was a fit subject for your consideration; and as such I beg to recommend it to your careful study.

INSTITUTION OF CIVIL ENGINEERS.

March 7th.—The Paper read was "*An Account of the Drainage of Paris*," by H. B. Hederstedt, Assoc. Inst. C.E.

Before describing the modern system, allusion was made to the manner in which the drainage of the city was effected up to the year 1808, when the subject first received thorough investigation, and after which numerous works were undertaken, so that by the commencement of 1832, there was a total length of drains of different kinds of 40,302 metres. The year 1832 marked an important epoch; for then the dreadful ravages of the cholera showed the absolute necessity for cleansing and draining the streets upon a better system than had previously prevailed. An accurate survey of the city, both above and below ground, having been made, levels were taken, and the principal features of each existing drain, or series, were recorded in a tabular form.

As Paris was situated wholly in the valley of the Seine, it was assumed that the drains should empty themselves into that river as far as possible, following the undulations of the streets in a more or less direct course. On the left, or southern, bank, where the city occupied an even and almost unbroken slope, the drains discharged directly into the river, independent of each other, and without consideration of their ultimate connection, by a tranverse sewer parallel with the river, as in the system now in use. The islands of St. Louis and Notre Dame dipped on each side of a longitudinal ridge coinciding with the centre line of the river, and their surface water at once entered the river, by drains on each slope. On the right, or northern, bank, there was one slope bordering on the river, down which the drainage passed into the Seine, and beyond this there was a dip in a northerly direction, towards the brook of Menilmontant, or the track of the "great drain," as it was called, which received the drainage of all the streets on this northern slope, and which finally fell into the river at Chaillot, some distance off on the west. The ridge of this slope was within the present fortifications, and from it descended another slope in a southern direction now lying beyond the fortifications, but the drainage of which could, if deemed desirable be placed in connection with the river on the north of and beyond Paris. There were thus five principal divisions, the left bank, the isles of St. Louis and Notre Dame, the right bank southernmost slope, the right bank northern slope, and the extramural slope.

The Seine was subject to heavy floods, but these were fortunately rare, as during the past two hundred and sixteen years there were only nine on record. In 1658, the surface of the river rose 28½ feet above its ordinary level. In 1802, when the last flood occurred, the river only rose 6¼ feet above the level of the discharging mouth of the modern drain at Asnières. These floods were more or less disastrous, sometimes lasting fourteen days, and submerging large areas of the city. To check their recurrence the low portions of the streets along the banks of the river were raised and walled in, to a point above the influence of floods so severe as that of 1658. There were, however, some parts of the city still exposed to floods, but their effects would be less disastrous, from the efficiency of the new drains, which carried off flood water almost as soon as the river level itself could subside, instead of leaving it to be absorbed or evaporated.

The progress of the drainage works might be gathered from this, that from the year 1832 to January 1837 the length of the drains was increased from 40,302 to 76,565 metres, while the new works in preparation and projected amounted to an additional 20,000 metres.

The position, cost, and object of the several drains, with the difficulties encountered in their construction, were then noticed. During 1833, thirty-three works were completed, of a total length of 15,008 metres, at a cost of about £5 13*s.* per metre. These included the first drain executed by tunnelling, the side walls of which were built in masonry and the arch in brickwork, at a cost of £8 per metre. In 1834, there were twenty-eight works, having a length of 6810 metres, and costing £3 17*s.* 6*d.* per metre. In 1835, twenty-two works were completed, being of the length of 8713 metres, at a cost of £3 13*s.* 9*d.* per metre. In 1836, new drains were built in several places, and a sewer was constructed in a quicksand, the rate of progress of which was 8 metres per day.

With regard to the sections of the drains, those of the old and of the new systems differed in two respects, the area of the latter was much larger than though not more effective, and footpaths and rails for carrying waggons were provided. In the former it was arranged that, as far as possible, all the drains should have a clear height of 6 feet, in order to insure their being properly cleansed. When this height could not be given, shafts were frequently added, to allow the workmen occasionally to stand upright. The minimum inclination of the drains was 1 in 1000; some were much steeper, and in these steps had been introduced in the inverts, principally at the points of junction with other drains. Up to the end of 1863 there were in operation 217 miles of drains, or more than four times the length in use in 1837.

As to the cleansing of the drains, before the introduction of the mechanical contrivances now in use, it was found necessary to employ hand labour, assisted by flushing, in many of the drains having an inclination of 1 in 1000, as that slope was found to be insufficient to carry off in suspension the solid materials of the drainage. In the smaller drains, rakes or scrapers of wood, cut to the contour of the invert, were worked backwards and forwards, until the mud was drawn to a shaft, through which it was lifted. In the larger ones the brush and rake were still made use of, aided by flushing. From both banks, and from the central islands, all the outlets poured direct into the river, and at the end of 1837, there were probably forty important outlets. Now, with three exceptions, all the discharging mouths had been abandoned, and longitudinal drains, parallel with the river, had been substituted. These finally discharged into the Seine at two places, one within and the other beyond the limits of the city.

A description was then given, showing the manner in which both the household and the rain water was disposed of. Night soil, it was remarked, had no connected whatever with the drains, except in one case. Most of the houses in Paris were built in blocks, with a central court-yard common to all, in which there was usually a cesspool for receiving the soil, whence it was removed at intervals. A new plan was now under trial in a few places, chiefly at barracks. This consisted in leading the night soil into cylinders perforated with fine holes, which allowed the liquid portion to rise in an outer cylinder, while retaining the solid matter within. The liquid portion was drawn off daily, and the internal cylinder was emptied as required. In all cases the night soil was carted away from the city, and was deposited in appointed places. A large quantity was converted into manure, at deodorising works, but only what found a ready sale was thus operated upon, so that much still went to waste.

The method of cleansing and the appliances to effect it were next noticed. Several of the main drains were composed of two principal parts, of which the lower, or water-way proper, formed but a small proportion of the entire sectional area. Those drains which had no separate water-way were cleansed by hand. The waterway, when forming a distinct part of the work, was of three standard sizes, all cleansed on one principle, but by appliances differing in detail. One was by a cleansing boat furnished with a scraper at the bow, which nearly filled the section, and was capable of motion in a vertical arc. This scraper formed a dam, and the water rising behind it afforded a motive power, which pushed the boat forward, carrying the mud with it. This scraper of course required constant adjustment; and instead of being a solid disc, it was provided with three openings, the central one of which was always open, while the others were fitted with sliding shutters. A simple arrangement at the stern of the boat kept it true to the axis of the channel. Under the most favourable circumstances it seldom happened that a length of more than 800 metres could be thoroughly cleansed in one day, owing to the necessity of going over some places several times. Some of the drains were cleansed by means of a small truck, used with apparatus like that of the boats.

In order to provide for the safety of the workmen, in the event of their being overtaken by a sudden rise of water above its normal level, safety chambers had been built in the roofs, which were reached by openings in the side walls of the drains. In June, 1855, the water rose in the outfall drain on the right bank of the Seine to a height of 4 ft. 11 in. above the level of the side footpaths, and in that on the left bank the water rose to 7 feet above the same level. Since then, many overflow weirs had been built along these main outfall drains, so as to carry off the surplus water after it had risen above the footpaths.

One leading feature of these works was the absence off small pipes, so constantly used in England; the smallest section ever built, under either the old or the modern system, being 5 ft. 6 in. in height, by 2 ft. 3 in. in width at the springing of the roof. As only a small portion of the total area was occupied by the waterway proper, the modern plan appeared to be very extravagant. In one case, the large space sacrificed for two water mains was instanced. Another source of heavy outlay arose from this circumstance: It might have been supposed, that one drain of the prevailing large sizes would fully satisfy the requirements of one street. This, however, was not so. A recent Act compelled all householders to build, at their own cost, private branches in communication with the street drain; and, apparently with a view of reducing the pressure of this Act, it had been established that in all new streets having a width of 72 feet, the City Commissioners should build a drain on each side of the street, so as to shorten the length of transverse drainage. These drains would be under the pavements, and the effect of this Act upon the householders would then be scarcely felt. During the early part of 1864, when the author was in Paris, he noticed the rapid progress of new works in several parts of the city; but in these no provision appeared to be made for the branch drains, which it might naturally be supposed would be proceeded with simultaneously with the main drains, to avoid the expense and inconvenience of opening the ground a second time.

The velocity of the current in the Seine was not sufficient to carry off the heavy matter discharged from the drains; consequently mud accumulated in the river-bed, which was cleared by dredging, at an annual cost of £3200, being at the rate of ten pence to one shilling per cubic metre. The maintenance of the system was most expensive, involving an outlay, during a recent year, of about £30,000. With respect to the drains at work, the author stated, as the result of several personal inspections, that there was a complete absence of unpleasant smell.

The materials used in the construction of the works of the old system were, a rough random rubble plastered,—a superior kind coursed—and ashler, chiefly for the inverts. Concrete was frequently employed in the foundations, as it was now; but the selection of lime for the masonry was formerly not considered important. At present, a course gritty sandstone was extensively used, set in random rubble fashion, the stone forming perhaps not more than 40 per cent. of the work, the staple material being mortar. The sand for this mortar was coarse and fine together, as taken from the pit; the result being a concrete rather than a mortar, which was employed in a dry stiff state. The work nevertheless was strong, attributable, it was believed, to good hydraulic lime being employed. Within the last three years a new building material, concrete, or béton 'Coignet,' had been introduced, the use of which had already been found to be satisfactory. This concrete was composed of sand, or ballast, dredged from the Seine, mixed with hydraulic lime and Roman cement. The cement was required to weigh 2800 lb. to 3100 lb. per cubic metre. This concrete cost £1 12*s*. per cubic metre in position in the drains, but the varieties of the mixture caused the price to fluctuate between £1 to £3 5*s*. per metre. The mode of building with this material was described in detail.

In conclusion, the author gave a schedule of the rates paid for masonry, and of the prevailing prices of the materials used in the construction of the works; and offered his acknowledgments to M. Belgrand, the engineer-in-chief, for courteously placing at his disposal all the records connected with the works, as well as for allowing him permission to inspect them.

March 14.—The Paper read was *"On the Metropolitan System of Drainage, and the Interception of the Sewage from the River Thames,"* by J. W. Bazalgette, M. Inst. C.E.

Before proceeding to describe the modern works for the drainage of London, which, even prior to the introduction of the improved system, was probably the best drained city of the present age, the author glanced at the early history of its sewerage. The minutes of the ancient Westminster Commissioners of Sewers contained records of peculiar interest; showing, amongst other things, that improvements for drainage were effected under the advice and instructions of Sir Christopher Wren, nearly two hundred years ago, and that the commissioners of sewers in the reign of Charles II., and subsequently. interfered to regulate the proceedings for the drainage of the Royal Palace in St. James's-park. Sketches attached to the paper represented the condition and appearance of some of the main valley lines,—as the Fleet Sewer, the Tye Bourne and the Bayswater Brook (now called the Ranelagh Sewer), and the King's Scholar's Pond Sewer,—taken from actual surveys in 1809. Up to about the year 1815, it was penal to discharge sewage or other offensive matters into the sewers; cesspools were regarded as the proper receptacles for house drainage, and sewers as the legitimate channels for carrying off the surface waters only. As the population of London increased, its subsoil became thickly studded with cesspools, improved household appliances were introduced, and, it having become permissive, overflow drains from the cesspools to the sewers were constructed; thus the sewers became polluted, and covered brick channels were necessarily substituted for existing open streams. These works, prior to the year 1847, when the first Act was obtained, making it compulsory to drain houses into sewers, being under the direction of eight distinct commissions, each appointing its own officers, were not constructed upon a uniform system: and the sizes, shapes, and levels of the sewers at the boundaries of the different districts were often very variable. Larger sewers were made to discharge into smaller ones, sewers with upright sides and circular crowns and inverts were connecte dwith egg-shaped sewers, or the latter with the narrow part uppermost were connected with similar sewers having the smaller part downwards. In the year 1847, these eight commissions were superseded by the Metropolitan Commission of Sewers, whose members were nominated by the government. The commission directed its energies mainly to the introduction of pipe sewers of small dimensions in lieu of the large brick sewers previously in vogue, to the abolition of cesspools, and to the diversion of all house drainage, by direct communications into the sewers, making the adoption of the new system of drainage compulsory; so that, within a period of about six years, thirty thousand cesspools were abolished, and all house and street refuse was turned into the river. Similar systems were, about the same period, to a large extent adopted in the provincial towns, by which means their drainage had been much improved, but the rivers and streams of this country had been seriously polluted. Within nine years, the Metropolitan Commissions of Sewers was followed by six new and differently constituted commissions, whose labours were duly recorded; but they were unable during the limited period of their existence to mature and carry out works of any magnitude. However, the subject of the purification of the Thames, then becoming full of sewage, received much consideration; and the late Mr. R. Stephenson, Mr. Rendel, and Sir W. Cubitt, who were members of the third commission, reported upon one hundred and sixteen competing plans, having that object in view, arriving at the conclusion, that none were such as could be recommended for execution. In 1850, the late Mr. Frank Forster was appointed chief engineer of the commission, and, under his direction, Messrs. Grant and Cressy commenced the preparation of a plan for the interception of the sewage of the area south of the river, and, Mr. Haywood, engineer to the City Commissioners of Sewers, assisted Mr. Forster in making a similar plan for the districts on the north side. In 1852, the fifth commission was issued, and the author became the chief engineer on the death of Mr. Forster. Two years later, the author was directed to prepare a scheme of intercepting sewers, intended to effect the improved main drainage of London, and Mr. Haywood was associated with him for the northern portion. The plan so prepared subsequently received the approval of the late Mr. R. Stephenson and Sir W. Cubitt, and was recommended for adoption.

In the year 1856, the present Metropolitan Board of Works was formed, —being the first application, in the metropolis, of the system of local self-government. The author, having been appointed engineer to the board, was instructed to prepare a plan for the main drainage, in which it was essential that ample means should be provided for the discharge of the large and increasing water supply consequent on the universal adoption of closets, and of the ordinary rainfall and surface drainage at all times, except during extraordinary floods; and that it should afford to the low-lying districts a sufficiently deep outfall to allow of every house being effectually relieved of its fluid refuse. The objects sought to be attained by these works, now practically complete and in operation, were the interception, as far as practicable by gravitation, of the sewage, together with so much of the rain-fall mixed with it as could be reasonably dealt with, so as to divert it from the river near London; the substitution of a constant instead of an intermittent flow in the sewers; the abolition of stagnant and tide-locked sewers with their subsequent accumulations of deposit; and the provision of deep and improved outfalls, for the extension of sewerage into districts previously for want of such outfalls, imperfectly drained. Prior to these works being undertaken, the London main sewers fell into the valley of the Thames, and the sewage was discharged into the river at the time of low water. In the system now adopted, it had been sought to remove the evils thus created, by the construction of new lines of sewers, at right angles to the existing sewers, and a little below their levels, so as to intercept their contents and convey them to an outfall 14 miles below London-bridge. As large a proportion of the sewage as practicable was thus carried away by gravitation, and for the remainder a constant discharge was effected by pumping. At the outlets the sewage was delivered into reservoirs on the banks of the Thames, placed at such a level as would enable them to discharge into the river at or about the time of high water. By this arrangement, the sewage was not only at once diluted by the large volume of water at high tide; but it was also carried by the ebb to a point 26 miles below London-bridge, and its return by the following flood tide within the metropolitan area was effectually prevented.

The points which required solution at the threshold of the inquiry, then successively noticed, were:—

1. At what state of the tide could the sewage be discharged into the river so as not to return within the more densely inhabited portion of the metropolis;

2. What was the minimum fall which should be given to the intercepting sewers;

3. What was the quantity of sewage to be intercepted, and did it pass off in a uniform flow at all hours of the day and night, or in what manner;

4. Was the rainfall to be mixed with the sewage, in what manner and quantities did it flow into the sewers, and was it also to be carried off in the intercepting sewers, or how was it to be provided for;

5. Having regard to all these points, how were the sizes of the intercepting and main drainage sewers to be determined; and

6. What description of pumping engines and pumps were best suited for lifting the sewage of London at the pumping stations.

As regarded the position of the outfalls and the time of discharge, an extract was given from the report of the late Mr. Robert Stephenson and

égouts is

Sir William Cubitt, dated the 11th December, 1854, referring to a series of experiments made with a float, by the late Mr. Frank Forster, and subsequently repeated by Captain Burstal, R.N., and the author, which proved that it was essential to go as far as Barking-creek, and that the discharge should take place at or near to high water. These experiments also demonstrated, that "the delivery of the sewage at high water into the river at any point is equivalent to its discharge at low water at a point 12 miles lower down the river; therefore the construction of 12 miles of sewer is saved, by discharging the sewage at high instead of at low water.

With respect to the velocity of flow and the minimum fall, it was difficult to lay down any general rule, because the condition of sewers, as to the quantity of deposit and the volume of sewage, varied considerably; but the results arrived at by Mr. Wicksteed, Mr. Beardmore, Mr. John Phillips, and Professor Robison were quoted, in confirmation of the author's own observations and experience, which led him to regard a mean velocity of 1½ miles per hour, in a properly protected main sewer, when running half full, as sufficient, especially when the contents had previously passed through a pumping station. Having thus determined the minimum velocity, it became necessary to ascertain the quantity of sewage to be carried off, before the fall requisite to produce that velocity could be estimated. That quantity varied but little from the water supply; and as it was contemplated that 31¼ gallons per head per diem might be supplied to a district, of average density of population, containing 30,000 people to the square mile, except in outlying districts, where the number of inhabitants was reckoned at 20,000 per square mile; and as actual measurement showed that provision for one-half of the sewage to flow off within six hours of the day would be ample, the maximum quantity of sewage likely hereafter to enter the sewers at various parts of the metropolis had been arrived at.

It had been advocated, by theorists, that the rainfall should not be allowed to flow off with the sewage, but be dealt with by a separate system of sewers. This would have involved a double set of drains to every house, and the construction and maintenance of a second series of sewers in every street, at an expenditure of from ten to twelve millions sterling, at the least, besides the inconvenience. Observations of the quantity of rain falling on the metropolis within short periods showed that, on an average of several years, while there were about one hundred and fifty-five days per annum on which rain fell, there were only about twenty-five days upon which the quantity amounted to ¼ of an inch in depth in twenty-four hours, or 1-100th part of an inch per hour if spread over an entire day. Of such rainfalls a large proportion was evaporated or absorbed, and either did not pass through the sewers, or did not reach them until long after the rain had ceased; for it was shown, in the report of Mr. Bidder, Mr. Hawksley, and the author, in 1858, that although the variations of atmospheric phenomena were too great to allow any philosophical proportions to be established between the rainfall and the sewer flow, yet, as a rule of avarages, ¼ of an inch of rainfall would not contribute more than ⅛ of an inch to the sewers, nor a fall of $\frac{1}{10}$ of an inch more than ½ of an inch. There were, however, in almost every year, exceptional cases of heavy and violent rain-storms, which had measured one inch, and sometimes even two inches in an hour. But it had been considered probable, that if the sewers were made capable of carrying off, during the six hours of the maximum flow of the sewage, a rainfall not exceeding ¼ of an inch in twenty-four hours on more than twenty-five days in a year, there would not be more than twelve days in the year in which the sewers would be overcharged, and then only for short periods during such days. The rare and excessive thunderstorms had been provided for, by the construction of overflow weirs at the junctions of the intercepting sewers with the main valley lines, which would act as safety valves in times of storm, when the surplus waters would be largely diluted, and, after the intercepting sewers were filled, would flow over the weirs, and by their original channels into the Thames.

Having thus ascertained the quantities of sewage and of rainfall to be carried off, and the rate of declivity of the sewer as limited only by considerations of the necessary velocity of flow, the sizes of the intercepting sewers were readily determined by the formulæ of Prony, Eytelwein, and Du Buat, and the drainage sewers by the useful formula of Mr. Hawksley, which it was said, in the report of the late Mr. R. Stephenson and Sir W. Cubitt, already referred to, were "applicable to almost every variety of condition which the complete drainage of large towns involves."

In regard to the sixth and last head of inquiry, in 1859, numerous competing designs, involving the comparative advantages of Cornish or rotative engines, and the respective merits of centrifugal and screw pumps, chain pumps, lifting bucket wheels, flash wheels, and every variety of suction or plunger pump and pump valve for raising the metropolitan sewage, were reported upon by Messrs. Stephenson, Field, Penn, Hawksley, Bidder, and the author. Based upon the recommendations contained in that report, condensed double-acting rotative beam engines, and plunger or ram pumps had been adopted; the sewage being discharged from the pumps through a series of hanging valves. The contractors for the engines at Crossness and at Abbey-mills, had guaranteed that they should when working, raise 80 million pounds one foot high, with one cwt. of Welsh coal.

It had already been stated, that a primary object sought to be attained by these works was, the removal of as much of the sewage as possible by gravitation, so as to reduce the amount of pumping to a minimum. To effect this, three lines of sewers had been constructed on each side of the river, termed respectively the High-level, the Middle-level, and the Low-level. The High and the Middle-level sewers on both sides discharged by gravitation, but for the two Low-level sewers the aid of pumping was necessary. The three lines of sewers north of the Thames converged to and were united at Abbey-mills, east of London, where the contents of the Low-level sewer would be pumped into the Upper-level sewer; the aggregate stream would thence flow throw the Northern Outfall Sewer, which was carried in a concrete embankment across the marshes to Barking-creek, where the sewage was discharged into the river by gravitation. On the south side, the three intercepting lines united at Deptford-creek, and the contents of the Low-level sewer were there pumped to the Upper-level, whence the three streams would flow in one channel through Woolwich to Crossness-point in Erith-marshes. Here the whole mass of the sewage could flow into the Thames at low water, but would ordinarily be raised by pumping into the reservoir.

As the intercepting sewers carried off only 1-100th part of an inch of rain in an hour, and the volume of sewage passing through them was at all times considerable, the flow through these sewers was more uniform than in drainage sewers constructed to carry off heavy rainstorms. The form, therefore, generally adopted for the intercepting sewers was circular, as combining the greatest strength and capacity with the smallest amount of brickwork and the least cost. In the minor branches, for district drainage, the egg-shaped sewer, with the narrow part downwards, was preferable; because the dry weather flow of the sewage being very small, the greatest hydraulic mean depth, consequently the greatest velocity of flow and scouring power was obtained by that section in the bottom of the sewer, at the period when it was most required; and the broader section at the upper part allowed room for the passage of the storm waters, as also of the workmen engaged in repairing and cleansing these smaller sewers.

A more detailed description was then given of the several works, and of some of the peculiarities or difficulties met with during their construction

On the north side of the Thames the High-level sewer varied in size from 4 feet in diameter to 9 ft. 6 in. by 12 feet. Its fall was rapid, ranging at the upper end from 1 in 71 to 1 in 376, and at the lower end from 4 to 5 feet per mile. In its construction, much house property was successfully tunnelled under at Hackney. Adjoining the railway station, a house was underpinned and placed upon iron girders, and the sewer, being there 9 ft. 3 in. in diameter, was carried through the cellar. This sewer also passed under Sir George Duckett's Canal; the distance between the soffit of the arch of the sewer and the water in the canal being only 24 inches. The bottom of the canal and the top of the sewer were here formed of iron girders and plates, with a thin coating of puddle, and no leakage had taken place. The Penstock and Weir Chamber, at the junction of the High and Middle-level sewers at Old Ford, Bow, placed three-fourths of the northern sewage completely under command. It was built in brickwork, was 150 feet in length by 40 feet in breadth, and was, in places, 30 feet in height. The principal difficulties in the prosecution of these works arose from combinations and strikes amongst the workmen, and a long-continued wet season preventing the manufacture of bricks; as well as from the great increase in the prices of building materials and of labour.

The Middle-level sewer was carried as near the Thames as the contour of the ground would permit, so as to limit the low level area, which was dependent upon pumping, to a minimum. The district intercepted by this sewer was 17¼ square miles in extent, and was densely inhabited. The length of the main line was about 9¼ miles, and of the Piccadilly branch 2 miles. The fall of the main line varied from 17½ feet per mile at the upper end to 2 feet per mile at the lower end. The sizes of this sewer ranged from 4 ft. 6 in. by 3 feet, to 10 ft. 6 in. in diameter, and lastly to 9 ft. 6 in. by 12 feet at the outlet. About 4 miles of the main line, and the whole of the Piccadilly branch, were constructed by tunnelling under the streets, at depths varying from 20 to 60 feet. This sewer was formed mostly in the London clay, but to the east of Shoreditch the ground was gravel. During the execution of the works under the Regent's-canal the water burst in; but by enclosing one-half of the width of the tunnel at a time within a coffer-dam, and then by open cutting, the sewer was subsequently completed. The Middle-level sewer was carried over the Metropolitan-railway, by a wrought-iron aqueduct 150 feet span, weighing 240 tons. The depth between the underside of the aqueduct and the inverts of the double line of sewers was only 2¼ inches; and as the traffic of the railway could not be stopped during the construction of the aqueduct, which was designed to be only a few inches above the engine chimneys, the structure was built upon a stage at a height of 5 feet above its intended level, and was afterwards lowered into its place by hydraulic rams. The sewers were here formed of wrought-iron plates, rivetted together. The Middle-level sewer was provided with weirs, or storm overflows, at its various junctions with all the main valley lines.

The length of the main line of the Low-level sewer was 8¼ miles, and its branches were about 4 miles in length. Its size varied from 6 ft. 9 in. to 10 ft. 3 in. in diameter, and its inclination ranged from 2 to 3 feet per mile; it was provided with storm overflows into the river. As well as being the intercepting sewer for the low level area, which contained 11 square miles, it was the main outlet for the drainage of the western suburb of London, a distance of about 14¼ square miles, which was so low that its sewage had to be lifted at Chelsea, a height of 17½ feet, into the upper end of the Low-level sewer. It was originally intended to deodorise or utilise the sewage of the western division in its own neighbourhood, rather than to incur the heavy cost of conveying it to Barking, and lifting it twice on its route to that place. But strong objections having been raised to this, the latter and more costly plan had been adopted. The works of this division were executed mainly through gravel, charged with such large volumes of water, that it was necessary to lay stoneware pipes under the inverts of the sewers, to lower the water in the ground, and to convey it to numerous steam pumps, before the sewers could be built.

The Northern Outfall sewer was a work of peculiar construction; for, unlike ordinary sewers, it was raised above the level of the surrounding neighbourhood in an embankment, which was of sufficient strength to carry a roadway, or a railway, on the top, should it ever be required to do so, as was not improbable. Rivers, railways, streets, and roads, on the line of this sewer, were crossed by aqueducts. The North Woolwich and the Barking railways were lowered to enable the sewer to pass over them; for the sewer, being reduced to a minimum uniform fall of 2 feet per mile, could not be raised or depressed like a railway, to accommodate its levels to those of previously existing works. This constituted one of the chief difficulties in laying out the Outfall sewer, for the district was already closely intersected by public works.

The Barking-reservoir had an average depth of 16¾ feet and was divided by partition walls, into four compartments, covering together an effective area of about 9½ acres. The ground over which it was built, being unfit to sustain the structure, the foundations of the piers and walls were carried down in concrete to a depth of nearly 20 feet. The external and partition walls were of brickwork, and the entire area was covered by brick arches supported upon brick piers, the floor being paved throughout with York stone.

The Abbey Mills pumping station,—the largest of the kind on the Main Drainage Works,—was furnished with engines of 1140 collective H.P., for the purpose of lifting a maximum quantity of sewage and rainfall of 15,000 cubic feet per minute, a height of 36 feet. This station alone would consume about 9700 tons of coal per annum; but the cost of pumping was not entirely in excess of former expenditure upon the drainage; for the removal of the deposit from the tide-locked and stagnant sewers in London previously led to an annual outlay of about £30,000. The substitution of a constant flow through the sewers, now rendered possible, must necessarily largely reduce the deposit, and consequently the expense of cleansing.

On the south side of the Thames, the High-level sewer and its southern branch, corresponding with the High and Middle-level sewers on the north side of the river, together drained an area of about 20 square miles. Both lines were of sufficient capacity to carry off the flood waters, so that they might be entirely intercepted from the low and thickly-inhabited district, which was tide-locked and subject to floods. The main-line varied in size from 4 ft. 6 in. by 3 feet at the upper end, to a form 10 ft. 6 in. at the lower end, the latter having a circular crown and segmental sides and invert; its fall ranged from 53, 26, and 9 feet per mile to the Effra, and thence to the outlet it was 2½ feet per mile. The branch line was 4½ miles in length; its size varied from 7 feet in diameter to 10 ft. 6 in. by 10 ft. 6 in., of the same form as the main line, by the side of which it was constructed. It had a fall of 30 feet per mile at the upper end, and of 2½ feet per mile at the lower end.

The Low-level sewer drained a district of 20 square miles. The surface of this area was mostly below the level of high water, and was, in many places, 5 or 6 feet below it, having at one time been completely covered by the Thames. The sewers throughout the district had but little fall, and, excepting at the period of low water, were tide-locked and stagnant; consequently, after long-continued rain, they became overcharged, and were unable to empty themselves during the short period of low water. The want of flow also caused large accumulations of deposit in the sewers, the removal of which was difficult and costly. These defects, added to the malaria arising from the stagnant sewage, contributed to render the district unhealthy; and it was with reference to its condition, that the late Mr. R. Stephenson and Sir W. Cubitt so forcibly described the effect of artificial drainage by pumping, as equivalent to raising the surface a height of 20 feet. The Low-level sewer had rendered this district as dry and as healthy as any portion of the metropolis. Its length was about 10 miles, and its size varied from a single sewer 4 feet in diameter at the upper end, to two culverts each 7 feet by 7 feet at the lower end, their fall ranging from 4 to 2 feet per mile. The lift at the outlet of the sewer was 18 feet. Much difficulty was experienced in executing a portion of this work, close to and below the foundation of the arches of the Greenwich-railway and under Deptford-creek, owing to the immense volume of water there met with. This was, however, at last surmounted, by sinking two iron cylinders, each 10 feet in diameter, through the sand to a depth of about 45 feet, the water being kept down by pumping at the rate of from 5000 to 7000 gallons per minute. The sewer was carried under Deptford-creek, and the navigation was kept open, by constructing a coffer-dam into the middle of the creek, and executing one-half of the work at a time.

The Deptford Pumping Station, where the sewage was lifted from the Low-level sewer into the Outfall sewer, was provided with four condensing, rotative beam engines, each of 125 H.P., and capable together of raising 10,000 cubic feet of sewage per minute, a height of 18 feet.

The Southern Outfall sewer conveyed the sewage which flowed into it from the High-level sewer by gravitation, through four iron culverts laid under Deptford-creek, and that which was pumped into it from the Low-level sewer, from Deptford through Greenwich and Woolwich to Crossness-point in the Erith-marshes. It was entirely underground for its whole length, 7¾ miles, was 11 ft. 6 in. in diameter, and had a fall of 2 feet per mile.

The Crossness-reservoir, which was 6½ acres in extent, was covered by brick arches supported on brick piers, and was furnished with overflow weirs and with a flushing culvert. Its height, level, and general construction were similar to that at Barking-creek. The ground upon which these works were constructed consisted of peat and sand, or soft silty clay, and afforded no sufficient foundation within 25 feet of the surface. The outlet of the Southern Outfall sewer was ordinarily closed by a penstock, and its contents were raised by pumping into the reservoir, which stored the sewage except for the two hours of discharge after high water. The sewage was thus diverted from its direct course to the river into a side channel leading to the pump well, which formed part of the foundation for the engine-house. From this well it was lifted by four high-pressure condensing rotative beam engines, each of 125 H.P., actuating, direct from the beam, two compound pumps, each having four plungers.

The tunnelling, and the formation of the sewers through quicksands, charged with large volumes of water, under various portions of the metropolis, more particularly in the low-lying districts on the south side of the Thames, were rendered practicable and safe by a mode of pumping the water out of the ground, without withdrawing the sand, which was adopted and perfected during the progress of the works. The method was to sink, in some convenient position near to the intended works, a brick well to a depth of 5 or 6 feet below the lowest part of the excavation. In some cases, where the depth was great, an iron cylinder was sunk below the brickwork, and the bottom and sides of the well were lined with shingle, which filtered the water passing into it, and exposed a large surface of this filtered medium. Earthenware pipes were carried from this well and laid below the invert of the intended sewer, small pits being formed at the mouths of these pipes, to protect them from the deposit. By these means, the water had been successfully withdrawn from the worst quicksands, and they had been rendered firm and dry for building on. The effectual backing of the invert and haunches with concrete formed, in such treacherous ground, it was asserted, the cheapest and best foundation. Numerous instances were mentioned of tunnels completed during the progress of the main drainage works, in peat and sandy soils charged with water, in the manner which had been described.

The bricks used in the works had been mostly picked stocks, frequently faced with gault clay bricks, and the inverts were occasionally faced with Staffordshire blue bricks. The brickwork was as a rule laid in blue lias lime mortar, mixed in the proportions of 2 of sand to 1 of lime for two-thirds of the upper circumference of the sewers, and the lower third had been laid in Portland cement, mixed with an equal proportion of sand. A considerable length of sewer had been laid entirely in cement. A double test of the quality of the cement had been employed, which had tended greatly to improve the manufacture of that material. The specifications provided that "the whole of the cement shall be Portland cement of the best quality, ground extremely fine, weighing not less than 110 lb. to the bushel, and capable of maintaining a breaking weight of 500 lb. on 1½ square inch, seven days after being made in an iron mould, of the form and dimensions shown on a drawing, and immersed in water during the interval of seven days."

There were about 1300 miles of sewers in London, and 82 miles of main intercepting sewers. The total pumping power employed was 2380 nominal H.P., with an average estimated consumption of 20,000 tons of coal per annum. The sewage on the north side of the the Thames at present amounted to 10 million cubic feet per day, and on the south side to 4 million cubic feet per day; but provision was made for an anticipated increase up to 11½ and 5¾ million cubic feet per day respectively, in addition to a rainfall of 28¾ and 17¼ million cubic feet per day respectively, or a total of 63 million cubic feet per day.

The total cost of the main drainage works would be about £4,100,000. The works had been executed under the immediate superintendence of the assistant engineers, Messrs. Lovick, Grant, and Cooper. The principal contractors had been Messrs. Brassy, Ogilvie and Harrison, Mr. Webster, Mr. Furness, Messrs. Aird and Sons, Mr. Moxon, Messrs. James Watt and Co., Messrs. Slaughter, and Messrs. Rothwell and Co. The works were now completed, with the exception of the Low-level sewer on the north side of the river, which was being formed in connection with the Thames embankment and the new street to the Mansion-house, and would therefore, probably not come into operation for a couple of years. The proportion of the area drained by that sewer was one-seventh of the whole. Some sections of the works had been in operation from two to four years, and the largest proportion for more than one year; so that the principles upon which they were based had already been fairly tested.

The communication was accompanied by numerous appendices, and was illustrated by a map of London, and by models and enlarged diagrams of some of the principal works. The author presented to the Institution a complete set of the specifications and of the contract drawings relative to the works.

THE RE-CONSTRUCTION OF MALAHIDE VIADUCT.

By W. Anderson, C.E.

(*Concluded from p. 72.*)

The webs consist of double systems of diagonal bracing (Figs. 6, 7, and 8, Plate 5) inclined at an angle of 45°, and presenting fifteen points of intersection with the flanges. Table 1 indicates the strain in tons, the sectional area in inches, and the unit strain in tons, on each bar of the bracing—calculated for the present paper with the aid of those most useful formulæ, for which the profession is indebted to our honorary secretary, Mr. B. B. Stoney, and which may be found fully worked out in the 'Quarterly Journal of Science,' for October, 1859. If W represents the load on each apex of a system of bracing, inclined at an angle θ with the vertical, and n be the number of loaded apices between any given diagonal and the abutment, then the strain on that diagonal will be $=(1+n)\,n\,\frac{W \sec.\theta}{2\,l.}$ when the first apex is distant one whole bay from the pier, and $n^2\,\frac{W \sec.\theta}{2\,l}$ where the first apex is only one half bay distant from the pier. That portion of the formula $\frac{W \sec.\theta}{2\,l}$ is a constant for every individual beam, so that the process of finding the pressure on each diagonal is simply multiplication by $(1+n)\,n$ or n^2, as the case may be. Table 2 gives the total strain, sectional areas, and unit strains in every portion of the flanges. In estimating the sectional areas available for duty, a deduction of ⅛-inch of surface all over the beam has been made, to allow for corrosion, which, as has already been stated, is extremely rapid. In the top flange, and compression lattices, no deduction has been made for rivet-holes. In the bottom flanges in which all the holes are punched, the cross section of the hole, augmented by one-fourth has been deducted, while from the tension lattice bars, in which the holes were drilled, their actual cross section has alone been taken. As regards the necessity of considering a punched hole as somewhat larger than its measured diameter, it is necessary to explain that, from several experiments recently made by the author, there can be little doubt that the material immediately surrounding a punched hole is sensibly injured by the violent straining it undergoes, and it is probable that from 0·2 to 0·25, added to the diameter of a punched hole, will be a safe correction.

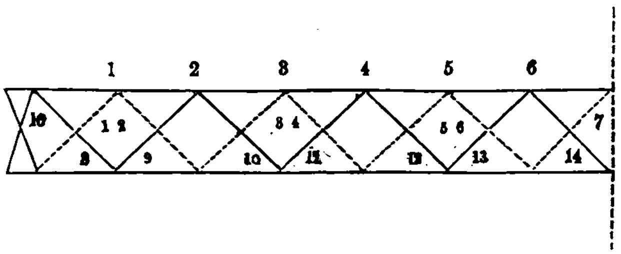
The cross-bracing connecting the six girders of each space gives rigid lateral support to the top flanges at four points, leaving, in the larger beams, a length of 22 feet in the centre to act as a column, with fixed ends. The breadth of the flange is 12 inches, or $\frac{1}{22}$ of the length, at which proportion Eaton Hodgkinson's experiments have shown that wrought-iron will bear very nearly a crushing strain without lateral deviation.

Table II.

Strain in Flange due to a uniform Load of 37 Tons.

No. of Space.	Top Flange.			Bottom Flange.		
	Maximum Strain.	Available Area.	Unit Strain.	Maximum Strain.	Available Area.	Unit Strain.
	tons.	sq. inch.	tons.	tons.	sq. inch.	tons.
0—1	7·92	9·50	0·83	9·24	5·44	1·7
1—2	23·76	9·50	2·5	25·08	5·54	4·53
2—3	36·96	15·37	2·45	38·28	10·52	3·64
3—4	47·52	15·37	3·22	48·84	10·62	4·6
4—5	55·44	21·24	2·61	56·66	15·38	3·61
5—6	60·72	21·24	2·86	61·94	15·38	4·03
6—7	63·86	21·24	2·98	64·58	15·78	4·09

The lattice bars in compression are all 1¼ inch thick in the larger, and 1 inch thick in the smaller beams, the breadth only being varied according to the strain. The sectional area of these is determined by the law, that the power of flat bars to resist a



compressive strain varies directly as the cube of the thickness as the breadth, and inversely as the square of the length. This law, which has been thoroughly investigated and experimentally

Table I.—Long Beams.

Strain in Diagonal Bracing due to 2·64 tons on each apex, and 5 tons moving over beam.

No. of Bar.	Maximum Compressive strain.			Available Sectional Area.	Unit strain.	Maximum Tensile Strain.			Available Sectional Area.	Unit strain.
	Due to uniform load.	Due to 5 tons passing.	Total.			Due to uniform load.	Due to 5 tons passing.	Total.		
	tons.	tons.	tons.	sq. inches.	tons.	tons.	tons.	tons.	sq. inches.	tons.
1	13·034	6·5	19·534	5¼×1 5·25	3·72	0·000	0·0	0·000	—	—
2	0·266	0·5	0·766	5¼×¾ 3·93	0·19	9·576	5·5	15·076	4⅛×¾ 3·1	4·8
3	9·576	5·5	15·076	4¼×1 4·25	3·55	0·226	0·5	0·726	3¼×1 3·2	0·23
4	1·064	1·5	2·564	4¼×¾ 3·19	0·8	6·650	4·5	11·150	3¼×¾ 2·4	4·65
5	6·650	4·5	11·150	3¾×1 3·75	2·95	1·064	1·5	2·564	2¾×1 2·7	0·95
6	2·394	2·5	4·894	2¼×¾ 1·69	2·53	4·256	3·5	7·756	1½×¾ 1·1	7·0
7	4·256	3·5	7·756	2¼×1 2·25	3·44	2·394	2·5	4·894	1½×1 1·5	3·26
8	0·000	0·0	0·000	5¾×¾ 4·31	0·00	11·172	6·0	17·172	4⅝×¾ 3·46	4·09
9	11·172	6·0	17·172	4¾×1 4·75	3·61	0·000	0·0	0·000	3⅝×1 3·6	3·00
10	0·532	1·0	1·532	4¾×¾ 3·56	0·43	7·980	5·0	12·980	3¾×¾ 2·8	4·64
11	7·980	5·0	12·980	4×1 4·0	3·24	0·532	1·0	1·532	3×1 3·	0·51
12	1·596	2·0	3·596	3¾×¾ 2·81	1·28	5·320	4·0	9·320	2¾×¾ 2·1	4·44
13	5·320	4·0	9·320	3¼×1 3·25	2·86	1·596	2·0	3·596	2¼×1 2·2	1·63
14	3·192	3·0	6·192	1¾×¾ 1·31	4·65	3·192	3·0	6·192	1×¾ 0·75	8·25
15	0·65	5·08	5·73	5¾×¾ 4·31	1·33	0·00	0·0	0·00	0·0	0·0
16	9·64	5·08	14·72	5¼×1 5·25	2·80	0·000	0·00	0·00	0·00	0·00

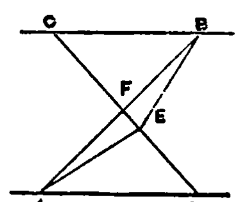
demonstrated by Eaton Hodgkinson, will be found very clearly set forth in that mine of practical information, E. Clark 'On the Britannia Bridge,' vol. i., page 318. From an average of eighteen experiments there recorded, on bars of various proportions, the author has calculated a constant for wrought-iron, which gives very nearly the strength of any bar whose length exceeds 30 times its least dimension. Let l=length in feet, t=thickness in inches, b=breadth in inches; then the breaking load in tons,

$$W=196\frac{t^3\times b}{l^2}.$$

It is hardly necessary to remark that in consequence of the difficulty of getting bars perfectly straight, perfectly uniform in texture, and in making the direction of crushing strain to coincide accurately with the centre of the bar, very great accuracy is not to be expected in such calculations.

In considering the length of the compression bars, a question arises as to whether the tension lattices, which intersect them in the centre, can be considered as securely fixing those points, as regards lateral deviation. Inasmuch as the weight of a flat pillar depends on the square of its length; this is a most important consideration, for if the tension lattice was capable of keeping the centre of the compression bar immovable, the latter might be regarded as two short pillars instead of one long one, and might, consequently, be made of lighter section. That the tension bars do actually give great lateral support to weak compression bars, may readily be seen in a great many existing bridges, even of large spans, where very long thin bars are loaded to a far greater extent than they could possibly sustain if not so supported. It is quite evident, however, that the tension diagonal can give no lateral support until the bars have already deviated from their original plane, so that distortion must have commenced before this support is available. As regards any increased strain on the tension bars from the extra duty they may thus be required to perform, it is easy to show that it cannot be considerable.

Firstly. Suppose the compression bar AB to bend in the plane of the beam to the extent FE, CD being the tension bar crossing it, it is quite evident that, if BF represents the strain passing down the bar, BE the resistance of the bent bar, FE will represent the force necessary to keep it in equilibrium, therefore the additional strain on CD will be the load on BA, diminished in the proportion the amount of deflection bears to half the length of the bar, which in practice is always a very small fraction.



Secondly. The effect of lateral deviation is to throw a tensive strain on CD, equal to the compressive strain on AB; because the angles at which the forces act being the same, equilibrium can only obtain when they are also equal. But as the loads on the tension and compression bars in any one part of a beam are very nearly equal, the strain due to lateral deflection can never greatly exceed what the tension bar is constructed to carry.

The rivets connecting the angle-irons to the flange-plates are ⅞-inch diameter; those connecting the lattice bars to the flanges vary from ⅞-inch to 1¼-inch, according to the section of the bars, the latter are all in double shear, and so arranged that the sectional area of rivets holding each bar is at least equal to half the area of the bar. Some extracts from the specification will best explain the remaining details of construction.

"'The position of the fish plates, at the joining of the flange plates and angle-irons, is not shown on the drawings, to enable the contractor to use the longest bars and plates possible; but it will be strictly required that the same available sectional area be preserved in every part of a beam as is shown on the drawings. No rivet may be used to fish the flange plates, except the two rows of ⅞-inch rivets shown on plans. No rivets may be used to fish the angle-irons except those of the flange plates or ⅞-inch rivets, in the same lines as the two rows fastening the diagonal bars. All holes in plates or bars, over ½-inch thick, must be drilled; but, if ½-inch thick, or under, they may be punched. All malleable iron used in this contract must bear a strain, by tension, of at least 20 tons per square inch of its sections in any part of the plate or bar. All cast-iron shall bear a strain, by tension, of at least 6 tons to the square inch of its section. The contractor shall provide for testing, in such way as shall be satisfactory to the company's engineer, 10 per cent. of the bars and plates to be used, the part to be tested being cut from the end or edges of the iron as shall be pointed out; and, if it shall happen that a sample tested of any lot gives way with a less strain than specified, it shall be in the power of the company's engineer, or any one acting for him, to reject the whole lot. All the beams shall be tested, if required, in the presence of the company's engineer, or some one acting for him, and to their satisfaction—the larger inside girders to 40 tons, the smaller to 30 tons, distributed."

It will be noticed that in this specification the quality of the iron is definitely fixed by a standard that can readily be measured, the ridiculous clause, hitherto in general use, defining iron by particular brands, is happily going very much out of fashion, though it is remarkable that it is not easy to get ironmasters to guarantee their iron to bear any given trial strain. The lattice bars were all rivetted to the flanges, by Cook's patent steam rivetting machine. It differs from Garforth's machines in not being direct acting. The steam cylinder is placed vertically, the connecting-rod, which works through a trunk, is connected to a lever, keyed on a rocking shaft, forming also an eccentric which actuates the rivetting die. Nothing can exceed the quality of work done by this machine. The author finds that it is equal to four gangs of rivetters, each gang being composed of 3 men and a boy. In doing plain straight work, 1500 rivets a day of ten hours can be put in. The rivets are heated in a small air furnace, as at the Britannia bridge. It was found impossible to close the 1¼-inch rivets, in a satisfactory manner, by hand. A head was indeed formed, but the body of the rivet remained quite loose in the hole. In rivetting by pressure the iron is forced into all the inequalities of the holes; in proof of which it is found that nearly one-half more iron is required to make an ordinary ⅞-inch rivet-head by pressure than by hand. The specimen of rivetting exhibited, two rows of which were done by this machine, and two rows by hand, at once show this difference.

The girders were all tested by laying on the specified weight of pig iron, before they left the contractor's yard. To facilitate this operation, two pieces of 12×4-inch plank, of a length equal to the span, were laid on the ground, the pig iron was piled on them, and the beam to be tested being laid on blocks, a few inches higher than the load, the weight was lifted on by means of ⅞-inch screws, passing in pairs through cross-heads resting on the beam, into the planks below. These screws were so spaced that a cross-head rested over every intersection of the lattices with the flanges. As soon as a beam was tested, the rods were unscrewed, the cross-heads removed, and the girder lifted out, without disturbing the load or screws, which were thus ready for the next beam. The deflections were taken by means of a fine line fastened at one end of the beam, and stretched by a weight, after passing over a delicately made pulley at the other. The deflections were very regular, and call for no special notice. The mean of the inner large beams was 0·55", that of the inner small ones 0·39". The time occupied in testing did not exceed a quarter of an hour.

In testing isolated beams of this description, the author has observed that, in consequence of the strain in the tension and compression lattices not passing exactly through the centre of the beam, but in planes at a short distance from though parallel to each other, a considerable tendency to twist is apparent, rendering it necessary to support the ends of the beam, on opposite corners, on the tension side. This circumstance renders it very important, in isolated beams, to divide the compression bars, and make the tension diagonals pass between them. In some small beams, recently made for the Royal Canal bridge, on the Dublin and Drogheda Railway, which were tested to 10 tons to the square inch, this twisting was so great that the load could not be laid on without fixing temporary hard wood pillars between the flanges over the abutments.

The specification originally provided that the iron-work was to receive two coats of oil paint; this, however, was given up in favour of a hot bath of coal tar, which was administered in the following manner:—Under the large travelling crane at the Dublin terminus, a cast-iron tank—53 feet long, 2 ft. 6 in. wide, and 5 feet deep—was erected, and filled with coal tar; under one end was placed a small furnace, with the flue running under and all round the tank to a chimney at the other end. As fast as the beams were delivered, the travelling crane deposited them, one at a time, in the tank, to simmer as long as the demand for them would admit; some, one hour; some, two days. When drawn out, they were allowed to drain for a short time previous to loading on the waggons. It is hardly necessary to state that this treatment ensured a most perfect coating of tar.

The beams having been lowered into their places by the travelling cranes on the bridge, were connected by horizontal and vertical cross-bracing. The former is composed of 8 bars, of 5" × ½" flat iron in each space, running at right angles to the beams, and rivetted under and over the bottom and top flanges. In the same plane with these, and secured in the same way, are the diagonal ties of 3" × ½" iron.

The vertical bracing is formed of 5"×2"×½" ⊥ iron diagonals, four sets to each span, rivetted to the inner sides of the flanges, directly under the 5"×½" flat bars, their ends being twisted and cranked, so as to admit their crossing each other and being rivetted back to back at their intersections (Figs. 5, 6).

The provisions for expansion in a bridge of this length, with slight piers, based on an uncertain foundation, was matter of anxious consideration, the more so, as the viaduct is on a gradient of 1 in 832; and it was feared that there might be a tendency in the whole bridge to work down to the lower end. To guard against this, Mr. Harty contrived a most ingenious and simple expansion apparatus (Figs. 9, 10). On every other pier, as already stated, the beams rested directly on metal wall-plates, but on the intermediate piers, their free ends were capable of motion on 2-inch metal rollers, arranged in wrought-iron roller frames. Furthermore, the ends of the bottom flanges were cut away on opposite sides, so as to pass each other, and were connected by pairs of short links, rocking on a centre pin secured in the wall-plate. By this arrangement the beams, though free to move, are yet secured to the piers, and the relative position of the two cannot alter. The author is not aware of a similar contrivance ever having been adopted before.

The maximum expansion of the Britannia bridge, 1510 feet long, is 6⅜ inches, (so that the Malahide Viaduct may expand 2·4 inches) or 0·4 inches on each expansion pier; considering, however, that the beams are very near the sea, and protected from extreme heat and cold by the timber sheeting, the actual amount of motion is not likely to exceed the half of that stated.

An inquiry of great practical interest, though, perhaps, not directly connected with the subject of this paper, is the relation between the theoretical and actual weight of beams, the relative quantity of material necessary to the flanges and webs respectively, and the amount of economy to be effected by reducing the flanges and webs in proportion to the strains.

With a view to illustrating this more clearly, Tables 3 and 4 have been constructed.

TABLE III.

	Actual Weight.		Actual Weight, deducting for Corrosion		Theoretical Weight of Beam to break under 4 times working load	
	lb.		lb.		lb.	
Top flange, ...	3805	32·82	3003	32·17	1745	41·40
Compression lattices	1473 }	23·06	1145 }	21·63	767 }	24·48
Tension lattices	1200 }		874 }		265 }	
Bottom flange ...	3805	32·82	3003	32·17	1438	34·11
Packings, joint-plates and rivet-heads	1309	11·29	1309	14·02	—	—
	11592	100·00	9334	100·00	4215	100·00

TABLE IV.

	Actual Beam, less allowance for Corrosion.			Theoretical Beam.		
	Uniform Section.	Section proportioned to Strain.	Per cent.	Uniform Section.	Section proportioned to Strain.	Per cent.
Top flange ...	3858	3003	77·8	2619	1745	66·63
Compression lattice	1456	1145 }	76·07	2387	767 }	32·37
Tension lattice ...	1198	874 }		801	265 }	
Bottom flange ...	3858	3003	77·8	2135	1438	67·35
	10370	8025	77·3	7942	4215	53·

In Table 3 it appears that, in the beam as it now stands, the weight of the flanges, which are equal, is two-thirds the weight of the whole beam; the remaining one-third being taken up by the web, packings, rivet-heads, and joint plates. The same proportion holds good when the ⅛-inch of surface allowed for corrosion has been deducted; but the packings, &c., which at present are 11⅓ per cent. of weight of the whole beam, become 14 per cent., as might be expected, since their weight is very slightly affected by the deduction. In the last two columns of the table are the weight of a beam supposed to be cut out of solid iron, with every portion accurately proportioned to the strain, which in the top flange is taken at 4 tons to the inch; in the bottom and tension lattices, at 5 tons; and in the compression bars to one-fourth the breaking load, by the formula

$$w = 215 \frac{n^3 b}{l^2} .*$$

The flanges in this case absorb three-quarters of the weight; the lattice bars only one-fourth. The quantity of iron sacrificed to compensate for corrosion is a little over a ton per beam, representing about £768 in the entire bridge; whereas, the unavoidable waste of iron in overlaps, packings, joint-plates, rivet-heads, exclusive of the ton above noticed, is nearly 46 cwt., more than 46 per cent.

Table 4 gives a comparative view of the amount of saving effected by reducing the flanges towards the ends, and the webs towards the centre. Thus, in the beam as it now stands, there is a saving of 22 per cent. in the flanges, and 24 per cent. in the web, being a saving of nearly 23 per cent. in the whole beam; whereas, in the theoretical beam there appears a saving of 33⅓ per cent. in the top flange, nearly 33 per cent. in the bottom, and 68 per cent. in the web, and 47 per cent. in the whole beam. As regards the flanges in this case, the saving is what may be inferred without actual calculation, because it is well known that the area of a parabola is two-thirds that of the circumscribed rectangle; now the flange of a uniformly loaded beam ought to vary in section as the ordinates of a parabola, consequently its weight should be two-thirds that of a flange of uniform section throughout. It may then be assumed, without much error, that the flanges form, generally, two-thirds the weight of a beam, the diagonals and packings, &c., one-third; that in practice it is possible, generally, to save one-fourth the material, by carefully proportioning the several parts.

In the large tubes of the Britannia bridge the weight of the top and bottom flanges is nearly equal, while the sides are a little more than one-third the whole weight—viz., 37 per cent.

From these considerations it is very easy to arrive at a quick method of estimating the weight of any given girder. The sectional area at the centre of one flange being obtained, the weight per foot is known, one-fourth of this, at least, may be saved by proper arrangement of the materials, and the weight of the whole beam will be three times this result.

The Board of Trade limit the strain on wrought-iron to 4 tons to the square inch in compression, and 5 tons in tension; this would make the bottom flanges of beams lighter than the top, were it not for the weakening effects of rivet holes; it is therefore generally correct to make the bottom flange the same gross area as the top. By dividing the strain in tons in the centre of a flange by 4, we obtain the sectional area; multiplying this by 3⅓ lb. the weight of an inch square bar, a foot long, we obtain the weight per foot of the flange; multiplying this into 3 we obtain the weight per foot of the beam, supposing its sections to be uniform; and finally, multiplying by ¾ths we get the average weight of a beam, the flanges and lattices of which are proportioned in some degree to the varying strains. If we assume the depth of a beam to be 1 foot in 12·8 feet, a very good proportion, this formula becomes

$$\text{Weight per foot } \frac{W \times 12{\cdot}8 \times 3\tfrac{1}{3} \times 3 \times 3}{8 \times 1 \times 4 \times 4} = 3W.$$

Or in other words, multiply the distributed load in tons a beam is required to carry, by 3, and the result is the weight in lb. per foot of the beam. This rule will be found very useful in making rough estimates of bridges.

The contract price for all the iron-work, including fixing beams in their places, and fitting in cross-bracing, but exclusive of carriage or placing the beams on the piers, was £6000. The wages paid for men employed in erecting and fitting bracing and expansion gear, amounted to £144, a little over 8s. per ton.

* The constant 215 is obtained from those bars crushed by E. Hodgkinson, whose scantlings were nearest to the sizes used.

After the beams had been fixed in their places, they were prepared for the reception of the 4-inch sheeting, by levelling over the plates and rivets with longitudinal timber packings, made to fit closely on the top flange, recesses being cut for rivet-heads joint-plates, &c. The planks were then laid across, in lengths generally equal to half the breadth of the bridge, with every seventh or eighth plank running right across. Where the short pieces met in the middle of the 6-foot space their ends were secured by bars of 3½"×½" flat iron, placed over and under the joints, and connected by a few bolts. The sheeting was secured to the beams by means of hook-headed bolts catching the flanges.

The following is the weight of bridge:—

	Per cent.	Tons.	cwt.	qrs.
72 beams	100	307	18	3
Cross-bracing	10·7	33	1	3
Rollers and frames ...	1·2	3	14	2
Wall-plates and joggles	4·6	14	8	3
		359	3	3

Memel timber was first obtained by contract at 1*s.* 10½*d.* per cube foot, delivered at the terminus, in plank, 4 inches thick, not less than 11 inches wide; but the quality and rate of delivery not proving satisfactory, Dantzic timber was obtained from an eminent firm on the North-wall, at 2*s.* 6*d.* per cubic foot, the original contractor being at the extra expense incurred thereby. The longitudinal sleepers were secured by wood screws to the 4-inch sheeting, and the rails laid in the usual manner. A simple post-and-rail handrail, on either side of the bridge, and a thin layer of clean gravel, to protect the timber from fire, completed the bridge.

Mr. Harty's original estimate of the cost of reconstruction was, £12,181 9*s.*, from which he deducted £300, the estimated value of old bridge, leaving £11,881 9*s.* as the sum to be expended. The actual outlay was £11,741 13*s.* 3*d.*, or £440 less than the estimate. The cost of this bridge is, therefore, a little over £20 10*s.* per foot. There are about 66 yards cube in each pier, making probably about 750 cubic yards, rock ashlar work and cut stone copings.

In order to ascertain the relative cost of the several parts of the bridge, and to separate those items easily estimated from the heavy contingent expenses, the following table has been arranged:—

Estimated cost of masonry in piers and abutments	£1800	20·13	per cent.
Piece-work in preparing dams, crane-roads, &c.	215	2·41	"
Ironwork in superstructure, as per contract	6000	67·09	"
Timber sheeting and handrail, at 3*s.* per foot cube	927	10·37	"
	£8942	100·00	
Miscellaneous expenses, such as cranes, sidings, switches, tools, watchmen, boats, &c. ...	2800	31½	"
	£11,742		

In comparing the cost of this viaduct with other bridges, it will be necessary to bear in mind the large allowance made for corrosion, and the circumstance, that the two outer ranges of girders are strong enough in themselves to carry a third line of rails.

In conclusion, it is necessary to explain that at the time this paper was begun, Mr. Harty was not a member of this Institution; that, beyond being contractor for the iron-work, the author had nothing whatever to say to the design or execution of the works, he has merely undertaken to record what struck him as being a valuable example of railway engineering.

The Ecoles des Beaux Arts, not only in Paris, but throughout France, have been supplied with many models and casts from the antique, and copies of the works of the great painters. A class for the study of engraving on precious stones has been opened here, under the direction of M. Farochon. Pupils are admitted between the ages of fifteen and twenty-five. For foreigners the permission of the Minister of the Fine Arts is requisite.

Reviews.

The Gas Works of London. By ZERAH COLBURN, C.E. London: E. and F. N. Spon.

A series of articles on the Gas Works of London, which appeared in *The Engineer* during the International Exhibition in 1862, have been reprinted in a convenient pocket volume, and present a very complete summary of the process of manufacturing gas, with special details relating to the gas supply of London. Various improvements have of late years been introduced in making, purifying, and distributing gas, and Mr. Colburn, by placing himself in communication with the engineers of several of the metropolitan gas works, and by an intelligent and able compilation of the information thus received, has set forth the existing condition of that important branch of manufacture in a very comprehensive and satisfactory manner. Without illustrative diagrams it is very difficult to convey a correct idea of the nature of the apparatus described, so as to be intelligible to those who are ignorant of the subject, but a general view is given, that seems to explain the principles on which the processes are conducted. The following general statistics of the gas works of London show the great magnitude which these undertakings had attained in 1861, and since that period the consumption of gas has greatly increased in the metropolitan districts.

"The metropolis, including a number of its suburbs, is supplied with gas by thirteen companies, owning nineteen works, all but two of which are within 4 miles from Charing-cross. The retorts, both single-end and double-end, are equal to almost exactly 5000 double retorts, averaging about 19 feet in length, or to 10,000 mouth-pieces. It has been estimated that these works carbonise 850,000 tons of coal annually, and from which about 8,000,000,000 (eight thousand million, or, in the ordinary terms of gas measurement, eight million thousand) cubic feet of gas is made. Of this upwards of one million thousand feet is lost by leakage from the mains and in other ways, while the rest is sold for about £1,400,000. Other estimates give 1,000,000 tons as the amount of coal carbonised yearly, the sale of gas and residual products amounting to £2,000,000, equal to 14*s.* 6*d.* for every man, woman, and child in the metropolis."

The accounts of the metropolitan gas companies for 1863, presented to Parliament last session, show that the total receipts of the thirteen gas companies that year amounted to £1,564,726, or about £150,000 more than in the above statement. The yearly gas rental of the Imperial Company, which is the largest in the world with the exception of the United Gas Company of all Paris, amounted to £419,060, or to more than one-fourth of the whole. The cost of the coal carbonised during the same year in the London Gas Works amounted to £706,170; and the united capital invested exceeds £5,680,000.

LONDON IMPROVEMENTS & LONDON DWELLINGS.

TO THE EDITOR OF THE CIVIL ENGINEER AND ARCHITECT'S JOURNAL.

As branch after branch of what may be called the intramural railways of London develops itself, sweeping away hundreds of metropolitan dwellings, the question—"How are the poor of London to be housed?" grows more and more difficult of solution. Nor are even these railways the only insatiable consumers of the space hitherto occupied by the poor, and by the struggling middle classes of the metropolis. The very facilities for connecting London with the provinces which railways themselves afford, tend to force upon Englishmen that system of centralisation which is not disliked on the continent, but it is a system that is not likely to be very popular in England. Mr. Bull has perforce to put up with it as he best can: he must expect to see the capital of the British empire cut up in all directions; and its denizens driven hither and thither, to make way for monster hotels for the housing of his country cousins; monster theatres, music halls, &c., for their delectation, and so on; just as he now sees one whole district of dwelling-house property destroyed, to make way for a central block of Government offices; and as he soon will see another large one swept away, to make room for a central block of law courts.

The last-named scheme, about to be realised under "The Courts of Justice Bill," will, according to *The Times* newspaper, displace no fewer than 343 dwelling-houses (which will include many respectable tradesmen's places of business, besides warehouses, and several large printing offices) chiefly inhabited by the working classes. Here surely is a greivous diminution of the already inadequate existing provision for housing the industrious where they are most wanted,—within the walls, so to speak, of our teeming metropolis. The relief afforded by the Metropolitan Railway, which now at a low rate enables the artisan to travel to and from the suburban districts, does indeed meet in some manner the wants of such work-people as building artificers and others, whose trades necessitate a moving about from place to place; and in the future railway lines, to be constructed around London, these cheap trains will become pretty general. But it should be remembered that not every class of people can contrive to move in and out of town in this regular way. Very many persons in London, especially in such districts as the neighbourhood of Lincoln's-inn, are compelled to live near their place of employment. This is particularly the case with the very persons whom the new courts of justice will disperse: law-stationers, letter-pressmen, compositors, wood engravers, and others, who follow precarious callings, quite incompatible with the observance of regular fixed hours for work and relaxation.

For such as these the cheap early trains will not suffice; however they may in the long run serve the necessities of the first-named class; and the remedy is palpable. There is nothing for it but the erection, and that without delay, of large blocks of associated chambers, or model dwellings; and this, be it observed, should not be done as an eleemosynary act, or with any parade of benevolently providing houses for the million. The English workman, under which term one may enrol about Lincoln's-inn many well educated middle-class men, hates to find a patron in his landlord. He is prepared to pay a fair rent for fair accommodation; so that really there is no excuse for treating him as a pensioner or a protégée. Charity model-houses, annually reported on, with a list of generous subscribers to the fund, and periodical treatises of the efficacy of cleanliness and sanitary regulations, are all very well in their way. If we mention them, it is not to decry them for a moment; but only to point to the fact that, for the purposes now called for, they are not the real thing required. The railway lines and other metropolitan improvements will displace, not merely the dwellings of the extreme poor; but those of very many persons of the middle class. For the former, blocks of dwellings in chambers, similar to those near old St. Pancras church, Streatham-street, St. Giles', and the just completed dwellings in Brewhouse-lane, Wapping, will, divested of the philanthropic element, answer every purpose needed; but for a very large class of Londoners a different description of model houses has long been wanted, and is now imperatively called for. What are really needed, and what would pay well, are two or three streets of such dwellings, designed as media between the present large blocks in and about Victoria-street, Westminster, and the poorer model houses before mentioned. There is nothing of the kind in London, that we are aware of. If companies can be got up, as we see every day, for working all kinds of private trades, irrigating foreign lands, and supplying with gas, water, and what not, towns and cities far away from their foci, the British metropolis; why cannot one hear of the formation of a company to meet this crying and daily increasing want; by, say, the purchase and removal of some central street-full of squalid, tottering lodging-houses (never designed for their present use) and the erection in their stead of a street-full of substantial dwellings in blocks, raised above a row of ground-floor shops or offices; and reached by wide handsome staircases, sparsely distributed along their frontage; to the great saving of space, and consequent saving of ground rent and of cost in construction? The times are very propitious for such a scheme; and more than this, they may even be said to demand its speedy realisation. W. Y.

[With the remarks of our correspondent we fully agree; there is not any necessity for such a wholesale destruction of houses as is contemplated, to obtain a site for the Law Courts. It is only some forty years since Soane erected his Law Courts, at great expense to the country. In the olden time, structures were built for public purposes, creditable to the locality and to the nation, and served for the purpose for centuries. Can it now be really necessary to demolish 7¼ acres of houses in almost the heart of the metropolis, for the sake of erecting "handsome Law Courts?" Might not the building for the Chancery Court be erected in Lincolns-inn-fields garden,—leaving a portion of the garden, ornamentally planted, surrounding it?" The King's Bench Court might have accommodation in the open space in the Temple by King's-bench-walk, and the Common Pleas and Exchequer could be erected on a portion of Gray's-inn gardens, their vicinity to each other being sufficiently close and their sites easily approachable. We do not think that any satisfactory reason can be assigned for giving the luxurious accommodation suggested, nor for such an expenditure. Quite enough of the metropolis is devoted to the members of the legal profession at present,—viz., Lincoln's-inn, Lincoln's-inn-fields, Bedford-row, Chancery-lane, the Temple, Sergeant's-inn (Fleet-street), Essex-street, Gray's-inn, Staple's-inn, Furnival's-inn, Barnard's-inn, Clifford's-inn, Clement's-inn and New-inn, besides many places in the vicinity of Guildhall—surely this is a large share of space in the capital to be occupied by one profession.—ED.]

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Award of the Medals and Prizes

A Special General Meeting of the Members was held on the 6th ult., Professor Donaldson, President, in the chair, to take into consideration the recommendation of the Council with respect to the award of the Royal Gold Medal, the Institute Medals, and other special prizes for the year 1864, and their recommendations with reference to the medals for the year 1865.

The resolution of the Council, containing their recommendation with reference to the award of the Royal Gold Medal, was first read. After some discussion it was decided that the Royal Gold Medal should be awarded to James Pennethorne, Fellow. The Report of the Council relative to the designs and drawings received in competition for the Institute Medal, the Soane Medallion, the late Sir F. E. Scott's special prize, and the Students' prize in books, was then read, and the prizes were adjudged as follows. To Mr. J. Tavenor Perry, Associate, for a set of drawings, sketches, and description of Bodiam Castle, Sussex, the Institute Medal and five guineas. To Mr. Harry G. W. Drinkwater, of Oxford, for a set of drawings, sketches, and description of St. Mary's Church, Iffley, Oxon, a Medal of Merit. To Mr. James Redford, of Manchester, for a set of drawings, sketches, and description of Croxden Abbey, Staffordshire, a Medal of Merit. To Mr. William Mansfield Mitchell, of Dublin, for a set of drawings, sketches, and description of Jerpoint Abbey, Kilkenny, Ireland, a Medal of Merit. To Mr. R. Phéné Spiers, of Pimlico, Associate, for a set of drawings and description of a design for an institute for the study, practice, and performance of music, the Soane Medallion. To Mr. J. Stacey Davis, of the Temple, for a set of drawings of a design for a mansion, the late Sir F. E. Scott's prize of Ten Guineas. To Mr. Thomas Brown, of Sheffield, and to Mr. James Howes, jun., of London, for designs for a gate-house and guard-house to a fortified city, a bath, an oriel window, a newel staircase, a group of furniture, &c., the Students' Prize in Books was awarded to both candidates.

The subjects for medals and prizes for the year 1865 were then taken into consideration, and approved.

BRADFORD WATERWORKS.

The Doe Park Reservoir.—The Bradford Waterworks Company have constructed three reservoirs for the purpose of supplying to mill-owners an equivalent for water which the company had abstracted from certain streams in the locality. The Doe Park Reservoir is one of these, and is capable of containing 110,000,000 gallons of water. The three reservoirs have together an area of about 160 acres. The outlay in constructing these reservoirs has secured to Bradford valuable drainage grounds amounting to above 10,000 acres, the water from which is both pure and soft. The conduits for bringing the water to the town are more than 30 miles in length, and include 5 miles of tunnelling. The works, which have cost about half a million, were carried out by Mr. Leather and Mr. Rooke, C.E., Leeds, and Mr. Gott, C.E., of Bradford. The subject of the security of the Doe Park Reservoir has on several occasions been brought before the House of Commons by Mr. Ferrand, M.P., and in consequence the Government commissioned Mr. Rawlinson, C.E., to visit and report upon it, as has been previously stated in this journal. Since Mr. Rawlinson's report, the Waterworks Committee have requested Mr. J. F. Bateman, C.E., to inspect this reservoir, and report upon it. This Mr. Bateman has recently done, and feeling that the subject is of great importance, and that the results of Mr. Bateman's careful examination will be interesting to the profession, we place before our readers his report to the Waterworks Committee:—

"Gentlemen, in compliance with your request, conveyed to me by a letter from the town clerk, under date of the 14th of January, I examined on the 27th of the same month, Doe Park Reservoir, with a view of giving an opinion upon its present condition. I was accompanied to the ground by the mayor, Mr. Turner (the chairman of your committee), the town clerk, and other members of the corporation, and by Mr. J. W. Leather, Mr. Gott, and Mr. Rooke, the engineers who had been engaged upon the work. We were met at the reservoir by Mr. Ferrand, M.P., Mr. Hulbert, Mr. Bennett (Mr. Hulbert's colliery manager) and other persons interested in the safety of the reservoir. I had pointed out to me on the ground all the various points at which the water was supposed to be leaking from the reservoir, and the drains by which the leakage was collected and conveyed away, and all the imperfections in the different parts of the work which were supposed to exist. My attention was also directed by Mr. Ferrand to all the circumstances which in his opinion were deserving of consideration, such as the absence of a side channel for carrying off flood-waters; the sufficiency or non-sufficiency of the means of passing off such water; possible injury to the stability of the bank which may have resulted from the trenches which have been cut into it for the purpose of repair; the necessity of having a resident watchman, and the danger of removing clay from within the site of the reservoir. The reservoir was full and overflowing at the time of my inspection, and the water had to be drawn down (by opening the valves of the discharge pipes) to enable me to enter the culvert through which the water, both from the discharge pipes and the waste ones, is carried away. According to the information I received, it appears that the valves were closed to allow the reservoir to fill on the 21st of December, 1864, and it was filled and running over on the 15th January. It had therefore been full for twelve days at the time of my visit.

The quantity of water issuing at various points at both sides of the valley, near the foot of the bank, and through the joints of the masonry of the culvert, was considerable, amounting, as nearly as could be estimated, to about 200,000 gallons per day. It was however, in all cases except one, perfectly clear and colourless, indicating that no waste of material was taking place. In the case of the single exception, discolouration did not arise from waste of material, but from the ochreous character of the water, which gave it a reddish, turbid appearance. This water was represented to be gradually collected from an old coal drift or heading, which was cut across by the puddle-trench of the embankment, at which point it was perfectly dry. Everything was, it was stated, made secure and water-tight at the point of crossing; and it appears, from observations taken, that in October 1861, when the reservoir was empty, the water from the drift passing over a 12-inch gauge-board, was 1½ inch in depth, while at the time of my inspection, after the wet weather, which had filled the reservoir in twenty-five days, it was only 1⅝ inches. During the summer of 1864, remarkable for the absence of rain, and the low state of the springs, it increased ⅜ of an inch over the same gauge. The obvious inference is, that this water is supplied from other sources than the reservoir, although that may contribute to increase its volume.

Water issues in several places in that part of the discharge culvert which lies between the waste well and the centre puddle wall, but there are only two cases of sufficient importance to require notice; one is that which comes from a pipe, 1⅞ inch in diameter, which has been inserted in the invert of the culvert, for the purpose of discharging water which was met with at that point. It is said to flow constantly, whether the reservoir is full or empty; and when I saw it, it was issuing languidly, without any force, although the water in the reservoir stood 53 feet above it. The other case was that of water issuing under some pressure from a joint in the masonry. Mr. Hulbert stated that near this spot he had observed, on a recent visit, a jet of water, about the size of a "pipe-stem," which issued from a joint about two feet from the bottom of the culvert, which is not now visible. It was stated that this was to be accounted for by the fact of some men having been, in the meantime, employed to caulk, or point up with cement, several joints through which the water passed, with the intention of driving it all to one spot, where its quantity could be more easily determined, and that the result was the strong issue of the joint which I observed. The jet alluded to by Mr. Hulbert appears to be the same which Mr. Ferrand spoke of as arising 2 feet in height above the point of issue, by the force of pressure, having evidently misunderstood Mr. Hulbert's description. Water in considerable quantity issued from the paved tail bay, at the lower end of the culvert but all this came out charged with so much ochreous matter as to colour and coat over the paving. This appearance indicates the probabitity of the water having passed for some distance through beds of coal-shale, and is inconsistent with any dangerous leakage or waste of materials.

One leakage on the left bank of the stream was said to have broken out for the first time, a few days previous to my visit. The quantity amounted to about ⅜ of an inch over a 12-inch gauge, and the water was perfectly clear, from which I infer that it could not have been of so recent a date as was supposed, although it might not have been previously observed. It flowed principally out of an old drain, which might have become stopped, and so forced out the water at a fresh point.

Almost all leakages tell their own story, and give evidence which may generally be implicitly trusted. If the water issues without force, and perfectly free from discolouration or matter in suspension, there is no danger, although the amount may be considerable. It is an evidence either that water passes through fissures of rock strata, or through sand or gravel, without waste of material. It is possible nevertheless that water may have passed through or in contact with the earthwork or puddle of an embankment, which it may have wasted or carried away, and may thus have lost the discolouration which it would have inevitably obtained by passing subsequently through a bed of sand or gravel before it made its appearance at the surface. This is an improbable supposition when the water issues close to the foot of a bank, but should it occur, still there is no immediate danger, and the leakage and its attendant circumstances, if continually and carefully observed, will disclose the true state of the case in ample time to allow of measures being taken to prevent mischief. If the leakage is stationary in quantity, or decreases, the circumstance in either case is a satisfactory sign. If it increases, but still remains clear, then there is a probability of the existence of the condition of things supposed; and a settlement of the bank, following the waste of material, and immediately over the spot at which it has occurred, may be looked for. Immediate danger however from such a cause, if that be the only one, is not to be apprehended, but, of course, a reservoir in such a state must be drawn down, and means taken for remedying the evil.

Now having regard to all these circumstances and considerations, I am of opinion there is no dangerous leakage from the reservoir. The quantity is large considering the comparatively small height of the bank, much more than could be desired; but so long as it remains stationary in quantity, with the reservoir full, colourless and free from matter in suspension, and no unusual or uneven settlement of the bank takes place, no mischief is accruing, and there is no ground for apprehending danger so far as the leakage is concerned; but there are other important points to consider with reference to the stability of the work, which I will now enter upon. The reservoir has on one or more previous occasions failed to retain water with safety after the works have been supposed to be finished, and the reservoir has been filled. These failures appear to have arisen mainly from two causes. 1. From the fact of the puddle trench not having been carried down nor tied at the ends to sufficiently retentive strata: and 2ndly, from imperfections in the puddle wall itself, which allowed water to pass through, and created what must have been dangerous leaks. It was the wish to discover the places at which these imperfections existed, and to remedy the evil, that induced Mr. Gott to adopt the bold and hazardous experiment which was condemned in the early part of last summer, and which was abandoned in consequence of the correspondence with the Home Secretary. This was to sink a trench on the outside of the puddle wall, retaining such a quantity of water in the reservoir as would keep its surface several feet above the bottom of the trench, so that the pressure would force the water through the imperfect parts and indicate the places at which repairs were necessary. In this way Mr. Gott appears to have discovered where the imperfections were, and he has consequently been able to repair them without reconstructing the embankment. He has also deepened and continued the puddle wall, so as to tie it to more retentive ground than was done at first.

A "fault," or dislocation of the strata, crosses the valley immediately below the site of the embankment, and is what the colliers call an "upthrow." This f ult is said to be watertight near the line of rupture, but the strata near are broken and tilted upwards till they have assumed a very steep inclination, dipping to the south-east, and consequently into the hill, in a contrary direction to the fall of the valley. Where they pass under the embankment they are not so highly inclined as near the fault, but they still dip in the same direction. This disposition of the strata has a very important bearing on the stability of the work. Had they inclined in a contrary direction, dipping down the valley instead of up, there might have been the danger of the bank, or a portion of it, or the base on which it stood, slipping downwards, as in the case of the Bradfield Reservoir of the Sheffield Waterworks, especially where the base might have been lubricated or the material softened by the water which evidently finds its way through the broken and dislocated strata. As it is, there is no fear of this danger, and from the examination which I have made of the plans and sections, showing the extent and depth to which the puddle walls have been carried, there seems every reason to hope that effectual means have been taken for remedying, as far as possible, the imperfections which have been discovered. Still the work of reparation has been very rapidly executed, and though everything at present indicates security, there has hardly yet been sufficient time for perfect consideration and satisfactory test. It ought to be mentioned that some of the water which breaks out between the fault and the foot of the embankment, and appears as leakage from the reservoir, is probably due to the peculiar geological condition of the ground, and is not attributable to the reservoir.

The provision which has been made for carrying off the flood waters is sufficient for the purpose; but as much apprehension has been excited on this point, especially in consequence of the disastrous effects of a very heavy flood which occurred in the same valley, in July 1856, previous to the construction of the reservoir, and which filled the neighbouring coal workings with water, it will be well to exemplify the case by a few observed facts and calculations. The flood waters are discharged by means of a circular well or swallow, the top of which forms the waste weir, the internal circumference of the well being the length of the weir. This is 46 feet, and it is assumed by Mr. Leather that no flood is ever likely to occur which will exceed a depth of 24 or 26 inches over this length. This is equal in quantity of water coming off the ground to 250 or 300 cubic per second from every 1000 acres of collecting ground, and to a depth of upwards of 7 inches over the whole surface, should it continue to flow at the same rate for 24 consecutive hours. Such a quantity of water flowing off the ground would probably represent 9 or 10 inches of actual rainfall in a day, an unheard of quantity in this district. The provision, therefore, may reasonably be supposed to be sufficient.

The total gathering ground above the reservoir is 1900 acres, and the total quantity to be discharged over the waste weir, at the rate of 300 feet per second from each 1000 acres, would be 570 cubic feet per second. This would require a depth of about 27 inches, which would leave the surface of the water still nearly 4 feet below the top bank, and it might therefore be passed off without any danger to the embankment. The culvert through which the water flows from the bottom of the well is capable of carrying away a much greater quantity without pressure and without danger. Floods may, however, occasionally occur, which at their maximum volume for short periods may exceed the quantity assumed by Mr. Leather. Such must have been the case on the occasion of the flood of July 1856, which drowned out the coal workings in the valley below the embankment. The effect of reservoirs is to reduce and moderate, and, if they be large enough, to absorb and destroy such sudden floods. For instance, if they occur at seasons when the reservoirs are empty, they may not be sufficient to fill them, in which case there would be no flood at all below the reservoir. If the reservoirs be full, then the flood has to spread itself over an extensive surface instead of being confined to a narrow valley. In the one case it may rise many feet in an hour, whereas in the other case it may be many hours in raising a foot. I have before me the record of all the great floods which have occurred at the Manchester waterworks during the last seventeen or eighteen years, and at many other places in the same range of hills in which the Bradford waterworks are constructed, but where the elevation of the hills is much greater, the declivities of the mountain sides steeper, and the rainfall much in excess of that which has been observed in the drainage area of the Doe Park Reservoir. There have been very few floods which have exceeded the volume provided for by Mr. Leather, in designing and executing the Bradford works: but I have an instance at the Manchester waterworks of a flood flowing at the rate of 375 cubic feet per second from each 1000 acres for two and a half hours consecutively; another which for seven hours and forty minutes averaged 300 feet per second from 1000 acres, and one instance, from somewhat doubtful data, appears to have reached at its maximum 500 cubic feet per 1000 acres, but this was for a very limited period. Assuming, by way of illustration, 400 cubic feet per second from 1000 acres, or 760 feet per second from the 1900 acres of drainage ground, and the reservoirs 31 acres in extent brimfull at the time of such a flood, it would take several hours before the depth over the waste weir rose to thirty-three inches; when the quantity passing out of the Doe Park Reservoir would be equal to the quantity flowing in, supposing no water were drawn through the discharge pipes. For this length of time the flood would be less by reason of the reservoirs, though full at the time, than if the valley were left in its natural state. No danger, therefore, need be apprehended on the score of the insufficiency of the means for discharging flood waters.

With respect to the absence of a side channel for carrying off flood waters, I can only say that, though such an arrangement would have been convenient and desirable, I do not consider it essential to the safety of the work. Supposing there were no flood at the time, the reservoir could be emptied by the discharge pipes, if need be, in less than two days, and even with a flood the operation could hardly be prolonged beyond four or five days. As far as my means of judging enable me to form an opinion, I do not think that such an interval would be attended with danger. It is alleged that it is injurious to cut away material from the inside of a reservoir, and complaint is made that the clay for the puddle has been so obtained. The propriety of adopting this course depends entirely on local circumstances. If the water-tightness of a reservoir depend on a thin superficial and unbroken coating or stratum of clay resting on open material, then it would be injurious to remove it, but where water-tightness and security are obtained by sinking deep into the bowels of the earth till a retentive stratum is met with, from which a water-tight puddle wall is raised in the centre of the bank, material within the site of the reservoir may generally be removed with impunity.

On the whole, therefore, although I cannot pronounce the reservoir to be in a perfectly satisfactory state, I believe the embankment to be secure, and the work free from danger, the provision for passing the flood waters sufficient, the arrangements for discharging the water well designed and executed, and the reservoir capable of holding the quantity of water required by the 51st section of the Bradford Waterworks Act, 1854. I consider it, however, necessary there should be a resident watchman, and that the quantity and chaarcter of the leakage and all the circumstances of the reservoir and works should be narrowly and carefully observed and recorded. Any change which indicates waste or danger should be immediately attended to; but so long as the leakage remains stationary in quantity and free from colour or matter in suspension, and the embankment retains its proper shape, I believe it is far better to leave the work alone, than to endeavour to reduce the leakage by any method which would disturb the ground.

In conclusion, I may be permitted to say, in answer to remarks in the correspondence which have taken place, that I have no connection with the reservoir, or the Bradford Waterworks, and that I have never professionally been consulted by the corporation with reference to the works they have constructed, except as to the Barden Reservoir, in which case I have recommended the reconstruction of the bank.

J. F. Bateman."

Notes of the Month.

The New Graving Dock, Sunderland.—The New Graving Dock at Sunderland has just been opened. The vessel first to enter the Dock was a ship of 1400 tons burthen, and to secure a sufficient depth of water up to the sill of the graving dock for the admission of a vessel of such large dimensions was a work of some labour, a large quantity of *debris* being lodged outside the cofferdam. The dredger Samson, and a large number of labourers were set to work in the beginning of the week, and by Wednesday morning a sufficient depth had been obtained to allow of the ship being floated from the dock basin to the sill of the new work. The following are the dimensions of the New Dock: length of first portion on blocks, 250 feet; ultimate length of dock, 450 feet; width of top 75 feet; width of bottom, 40 feet; width of entrance at 8 feet above high-water ordinary spring tides, 60 feet; depth on sill below high-water ordinary spring tides, 16 ft. 6 in. It was first intended to have this new work

450 feet in length, and ground has been made by the deposition of rock and earth in a south-easterly direction to carry out this plan. The commission, however, determined to finish a section of it 250 feet in length before proceeding with the rest of the work, and the contract for this was let to Messrs. Hirst and Sons for £14,000. Instead of entrance gates as in the old dock, the entrance to the new dock is closed by a hollow iron caisson, manufactured by Messrs. Hawks, Crawshay, and Co., of Gateshead. The caisson is considerably cheaper than wooden gates would have been, but much skill is necessary in fixing it in its place, and it will be some time before the dockmen get accustomed to it. It is about 8 feet broad at the top, on which there is a roadway, with ropes and rails on either side, and bulges out to a much greater diameter towards the bottom, where the chamber for the reception of the water is formed. When the caisson is required to fit into its place, at the entrance to the dock, water is admitted into its interior by means of valves in its sides, when it gradually sinks into its position, hermetically sealing the opening; when it is required to be removed for the ingress or egress of vessels, the water is pumped out by means of an apparatus worked upon a platform within the caisson, and it is floated to aside. The dock will be emptied by means of a culvert running to a well some four feet below the level of the dock, from which the water will be pumped by a powerful centrifugal pump, which raises 1000 gallons a minute with ease. The pump, with the steam engine by which it is worked, is situated between the two graving docks, and is used for the emptying of both.

Liquid Glue.—The use of this substance has become very extensive in France, and it may be useful to give the process by which it is obtained. A kilogramme (2¼ lb. avoirdupois) of good glue of Cologne, or Givet, is dissolved in a litre of water in an earthen pot plunged in hot water, the water lost by evaporation being replaced. When the glue is completely dissolved, one-fifth of a kilogramme of nitric acid at 30° Centigrade is added; the acid throws the solution into a violent state of effervescence, and a quantity of reddish coloured gas escapes. When the mixture has become quiescent it should be well stirred, set aside to cool, and placed in well-stopped vessels for future use.

Metallic Ceiling.—Mr. Little has invented a system for the construction of ceilings, which consists in the application to the joisting of very thin stamped ductile metal, in ornamental embossed panels, of such sizes and shapes as may be required. These stamped panels are fitted for every kind of decoration in colour, and, if inserted as plain surfaces, may be used as the ground for every description of cartoon painting, combining with lightness and durability artistic and ornamental effect, at a comparitively small cost. Besides its applicability to the ceilings of rooms, and all public buildings, churches, &c., the system may be made use of with the same effect in staircases, halls, and porticoes, and even on the walls of rooms. It affords the means, when coupled with an iron framing, of making theatres fireproof, thus avoiding those sad contingencies to which these crowded buildings are so exposed.

Public Works in New South Wales.—The opening of a branch railway from Blacktown to Windsor and Richmond, which took place on the 29th November last, was an event of much importance, not only on account of the benefit it has conferred upon a populous and fertile district, but also in relation to the question of railway communication in the colony. In order to lessen the cost of this railway, the works are much lighter in their character than those on the trunk lines. Should the new railway realise the expectations that have been indulged in, as to the suitability of the works to the nature of the traffic, the experience gained may be of value in the construction of future lines.—At Newcastle, progress is being made with the various works for the improvement of the harbour. The northern breakwater is being proceeded with; upwards of 1200 tons of stone were deposited in November last. The ballast is supplied by vessels coaling at the port. Preparations are being made for the repair of the southern breakwater, which was damaged by gales. Along the greater portion of the new wharf the water has been deepened, and vessels drawing seventeen or eighteen feet of water can now go alongside. The steamers' wharf is completed, and plans are being prepared for a commodious goods shed to be erected close to it.

The Collegiate School of Strasburg, in virtue of a bequest by M. Lamey, formerly Judge of the Civil Tribunal of that town, offers a prize of 3000 frs. for the best essay on the following theme:—"Should art be submitted to rules? On what do they rest? Are they absolute or relative, or partly one and partly the other? How is their authority to be reconciled with freedom of inspiration?" The prize is open to all the world, and the essays, which may be written in French, German, or Latin, are to be sent in by the 1st of January, 1867.

Pneumatic Application of Ammoniacal Gas.— M. C. Tellier, whose proposed application of ammoniacal gas to locomotion has been previously noticed, now suggests a more simple application of the same substance, that of using it to create a vacuum or partial vacuum, for industrial purposes, such for instance as the emptying of cesspools. The method proposed to be employed is to fill an iron receiver with the gas in question, and convey it to the spot where the vacuum is required. At the upper part of the receiver is a small reservoir containing water, and which communicates with the interior of the receiver by means of a stop-cock; when this is opened the water rapidly absorbs the gas, and the required vacuum is obtained. The quantity of water necessary for this purpose is said to be in the proportion of six or seven litres to a cubic metre of gas. In order not to lose the ammonia, this is allowed to escape into another similar reservoir at the lower end of the receiver, before the connection is opened between the interior of the latter and the cesspool. With this arrangement the total cost, in addition to that of the apparatus and the original supply of ammonia, would, according to M. Tellier, be reduced to the value of the coal required to disengage the gas from the solution, and this he estimates at four or five centimes the cubic metre. M. Tellier contemplates many applications of this principle, but the above will sufficiently illustrate his views.

Public Monuments in France.—The labour, talent, and expense bestowed on the public establishments and monuments of the country have been enormous. Extensive restorations and decorations have been executed in the two great edifices of Notre Dame and Saint Denis, as well as in more than twenty churches in various parts of the Empire. The ancient Cité de Carcassonne, the Roman theatre and ampitheatre of Arles, the Chateau de Falaise in Calvados, the Temple of Diana, and the Roman Ampitheatre of Nimes, the Temple of Augustus and Livy at Vienne, the Abbey of Charlieu, in the department of the Loire, the Oratory of the Templars at Metz, the Chateau of Pierrefonds, the Chateau of Blois, the ramparts of Avignon, and other monuments of historic interest, have been repaired. Of the public establishments, directly or indirectly connected with art, the building where the archives of the Empire are kept has been largely extended, and the School of Archæology annexed thereto has had a special building provided for it. The restoration of the Palace of the Institute has been completed; the arrangements of the new school of Fine Arts terminated; the old Chateau of St. Germain has been almost entirely restored, with the view of converting it into a grand museum of Gallo-Roman productions; the arrangements of the interior of the new Louvre have been pushed forward: a fine new gallery has been prepared for the works of the French School, and thrown open to the public, a number of new rooms on both floors added to the gallery space in the new portion of the building, and several of the old rooms have been re-embellished and arranged at considerable cost; the corner building of the Tuileries by the river, known as the Pavilion de Flore, as well as a section of the grand picture gallery adjoining, have been completed as far as the masonry is concerned, and the whole of the remaining portion of the gallery has been levelled with the ground, and is now being rebuilt in the style of the adjoining work of Henry IV.; the reconstruction of the Bibliotheque Imperiale has been energetically pursued, and the new reading-room, modelled somewhat after that of the British Museum, is covered in, and will soon be ready for occupation; the famous manufactory of Sevres has been entirely rebuilt; and the new Opera House has been carried up from the basement to the first floor. This is a long list, perhaps the longest ever furnished by a single government, but it is far from complete, although it includes all the principal works connected with art which have been supported by the budget of 1864.

THE MANAGEMENT OF TOWNS.*

IV.—*The City of London.*

The enormous and still increasing stream of traffic that flows through the narrow streets and rapidly grinds away the surface of the pavement, whatever its material may be, can only with great difficulty be diverted into other channels when a particular street is closed for repair. The choice of the best materials for paving, and of modes of executing the work, is therefore of very great consequence, both with respect to economy, and the convenience of the public. Where these two happen to clash, it is frequently necessary to execute the works with regard to economy of time, rather than of money. The properties of various kinds of pavement in respect of hardness, durability, safety, and freedom from noise and dust, have consequently been made the subject of study and experiment for several years. Statements upon these matters, and upon questions of cleansing, watering, and gravelling the surface of paved roads, have been made, on several occasions, by Mr. Haywood, both in his annual reports and in separate documents called forth by the growing importance of the subject. At the present time the pavements in use are granite pitching, and wood, with small portions of macadamised roadway and experimental patches of iron and other pavements.

For several years past the only portion of macadamised road within the city has consisted of that in Finsbury-circus, a quiet locality of light traffic, where the prevention of noise is an important consideration. About forty years since this system was in operation in some of the busier streets, under the direction of Sir James M'Adam, but the experiment was not considered satisfactory by the authorities. At the present time, when some of the West End streets are being macadamised the question has an increased amount of interest, but it may be remarked that the traffic in those streets compares in no way with that in the City, the narrowness of the City streets being taken into account, and it is highly probable that, even if the macadamised roadway is found to be upon the whole desirable in such streets, this difference of condition will demand an equal difference in the system of pavement.

Between the years 1839 and 1851, about thirty-two streets and portions of streets were paved with wood, but in 1853, when the question of wood pavement in comparison with granite was reported upon by Mr. Haywood, twenty-three of these places had been repaved with stone, leaving nine portions of wood pavement still in existence. From the facts given, and the engineers' opinions, we gather that the cost of wood was considerably in excess of that of stone, and was likely to be still more so if wood were subjected to the severe traffic of some of the busiest streets, and were kept in the state of repair in which granite is regularly maintained. Nevertheless, wood pavement, as compared with stone, is so pleasant, both to pedestrians and to the inhabitants of the streets, that it may properly be used in some places even at increased cost. At present the streets paved with wood consist wholly of those in which the quietude under traffic which belongs peculiarly to this pavement is considered by the citizens of very great importance. They are laid by Mr. Carey, the patentee. It is considered necessary to sprinkle the surface thinly with fine gravel in frosty weather and in very greasy states of the streets, and an occasional dressing indurates the surface. With this precaution and the necessary repairs the pavements appear to be safe and comfortable in use.

An experimental portion of cast-iron carriage-way pavement, consisting of polygonal open blocks locking to each other, notched upon the edges which form the surface, and filled with gravel, was laid in Leadenhall-street towards the end of the year 1855, and relaid upon a bed of concrete in November 1856, but having got into bad repair early in 1857, it was removed in April of that year. Leadenhall-street is in the line of great and heavy traffic, and may be said to offer a severe test for any kind of pavement; so it is to be presumed that some grounds were seen for anticipating a more satisfactory result from the use of castings of an improved description and much heavier; for in May 1862, such blocks were laid down in the Poultry, which is very narrow, and has the greatest traffic of any of the City streets. From the narrowness of the street the wheels of vehicles are driven into regular lines, and quickly cut deep channels in the hardest description of granite, which necessitates the stoppage of the thoroughfare for repaving the whole width, at frequent intervals. This pavement having been laid in connection with a cast-iron tram which ran along the curb, became so much cut into at its junction with the tram, that in December 1863 it was taken up and relaid over the whole surface, the tram being omitted. This pavement is Knap's patent, laid by Crook and Co., contractors.

It is to be remarked that, except where failure occurs, a very long time is required for fully testing the value of iron as compared with other pavements. Their first cost is heavy and they are not capable of being used up so entirely as is the case with granite, which is useful, in one shape or another, to the last. The wear and tear of iron is indeed very small, and this is an important consideration in the City, where the first cost of a pavement is not a consideration of prime importance, as the trouble and loss to the public resulting from taking up and relaying a pavement are such as to induce the authorities to choose that which is most durable, even though the cost may be somewhat in excess of another which is less so.

The granite paving in many of the narrow streets which have but one line of traffic, consists of a broad tram of large blocks of stone laid on each side next the kerb to take the wheels, and of small granite cubes between. This is the easiest kind of pavement for horses to draw over, giving a smooth surface for the wheels and another surface sufficiently rough to afford foot-hold for the horses. Redman's patent cast-iron trams have, on account of their durability, been used in some cases instead of granite. In such streets the horses and the wheels are forced into those parts of the pavement which respectively suit them the best. Where the streets are wider this is not the case, and the sets are laid so as to butt against the kerb, or with one or two courses of the ordinary paving sets run longitudinally against the kerb, hardly forming a channel, but, no doubt, facilitating the flow of water in some degree. Cast-iron channels, slightly dished, have also been used, but the nature of the traffic differs so materially in different streets that no one plan is considered suitable for all cases.

In narrow streets of great traffic, where the wheels grind against the kerb, a channel is soon cut in the hardest granite, and where a tram is lain in such a street this channel is cut at the line of junction between the ordinary paving and the tram. Various plans have been tried by the engineer for reducing the wear and tear at this point, amongst others the cast-iron pavement elsewhere referred to, and a tram introduced by Mr. Carey which presents a broad surface of cast-iron close to the kerb where the wheels run, and has its outer side toothed, so that the alternate courses of 3-inch granite cubes bond into it, and leave no straight joint to catch the wheels.

The general description of pavement now in use in first-class streets is Aberdeen granite cubes, 3 inches on the surface, 9 inches deep, and from 6 to 12 inches in length, laid so as to form a very perfect bond. The foundation varies with the nature of the subsoil, but in general a bed of broken granite 12 inches thick is laid, and the pavement is set on a layer of gravel. The surface is then grouted with liquid mortar. This applies (except as to the foundation) to new paving only, but the amount of new paving that is required in the City is only so much as is necessary to supply the annual wear and tear. The great bulk of the work consists in the relaying of old paving materials, and with respect to this the following extract from a very full report, by Mr. Haywood, upon the comparative value of different paving materials (12 July, 1853) will give an idea of the system in use:—

"The practice pursued in all cases, with regard to the carriage-way pavings, is to lay the new granite in the leading thoroughfares, and after a certain amount of wear has been had of them —when the stones have either lost considerably in depth, or require redressing before they can be relaid with advantage, then instead of performing that troublesome and tedious operation in the principal thoroughfares, and causing the inconvenience to business and the traffic, by stopping up main streets for long periods, new stone is laid down and the old stone is relaid (after it has been redressed) in some street of less traffic. This custom has been, more or less, pursued for many years—it has not been invariable it is true, for, as in all such arrangements, economy has not been lost sight of, the removal of stone from a principal thoroughfare has depended in some degree upon the requirements of other localities; as, for example, whether suitable places to receive the worn paving were in need of reparation, or repaving, at the same time as the larger thoroughfares, or whether arrangements could be made for at once carting away the stone from one to the other, &c.; but of late years the increased traffic,

* Continued from page 90.

and the additional inconvenience experienced by the stoppage of an important highway, has induced your honourable court to make considerable sacrifice in this particular, and stones are now scarcely ever dressed in the main thoroughfares within your jurisdiction, but are at once either carted away directly to other localities, and there dressed and laid, or to the stone yard, where after dressing they are subsequently carted out and re-laid, when and where required......Indeed, with the exception of the portion worn off by the friction of the traffic, not a fragment of granite paving can be said to be lost. After passing its first years in a leading thoroughfare, it goes into a secondary thoroughfare until completely worn down and rounded, and will even then command the before-named price, not even a frament that is knocked off the component stones, when undergoing the operation of being dressed into shape, is lost; as it is made available either directly for macadamizing, or forming sub-strata to other pavements, or if such employment cannot be found for it, it will always command a good price by its sale. In truth, granite, unlike wood, which is subject to decomposition, can only be said to be worn out when it has been broken up for macadamization, and then crushed into powder by the vehicles"

The engineers' estimate for the duration of granite pavement in a particular street of considerable, but not excessive, traffic was from 16 to 18 years, more or less, it would then be removed to streets of inferior traffic, there it would last for an equally long or longer period, and under such arrangements as have been described granite cubes might last from 30 to 40 years, and would still be valuable for other purposes.

The pavements, especially those in the principal streets, are carefully inspected daily, as already stated, and all depressions at once repaired. The engineer has stated that this produces a positive saving in expense, as the stones when out of repair suffer to four times the extent of similar pavement when in good repair. There are therefore constant trifling reparations performed without stoppage of the traffic, being chiefly done before 8 o'clock a.m. When patching appears to be no longer effectual or economical, they are repaved.

Street Cleansing and Watering and Removal of Dust.—In each of the four districts into which the City is now divided, as mentioned under the head of Inspection, the cleansing and removal of dust are let to a contractor—the watering is let separately. The streets, courts, alleys, the public markets and all other public places or thoroughfares, are cleansed every working-day. From April to September, both included, this cleansing is, in the smaller streets, performed between 4 o'clock in the morning and 1 o'clock in the afternoon, and during the remaining months it is done between the hours of 5 a.m. and 2 p.m. The main streets are cleansed between 4 and 9 a.m.; and these streets, as well as the public markets, are in addition cleansed every Saturday afternoon, at such times as the inspectors may direct. The contractor is bound to cleanse any street a second time in any day, if directed by the inspector so to do. Courts are, where necessary, washed by means of the hose and jet, evidence of which may be found in the items of £146 9*s*. 4*d*. and £112 19*s*., paid during 1863 and 1864 respectively to the water companies for water supplied by them for that purpose.

As regards streets having both carriage-ways and foot-ways, this cleansing only takes place on the carriage-ways only. When it has been completed, that is by 9 a.m. in the best streets, at which hour they should of course be clean, the inhabitants are bound by law to cleanse the foot-ways, depositing the dirt, the amount of which is not inconsiderable, upon the newly cleansed carriage-way. It is certain, from frequent observations, that very many of them supplement this deposit, contrary to law, with a large addition in the shape of domestic dust and the refuse of trade: the attention of the commissioners has been drawn to this, but the remedy is in the hands of the police, who alone can detect offenders, and it is under the police act the offence is punishable. It nevertheless goes on openly in localities of a particular kind all over the metropolis, though dustbins are provided and can be emptied, free of charge, as often as the householders see fit to require. By those who are responsible for the condition of the streets in respect of comfort and health, this is felt to be a crying metropolitan evil. In the present state of the police regulations, in which the attention of the constables appears, perhaps necessarily, to be directed, not regularly towards infractions of the law while they are growing into customs, but spasmodically against such as have become too gross and open to be longer overlooked, we would say that this is of the latter class, and should be taken in hand without delay.

The dustmen are bound, twice a-week at least, to call at every house, and ascertain if the occupiers require the dust to be taken away; if required then or at any other time, they must thereupon remove the same, the penalty for omitting either to call or to remove the dust when required being twenty shillings for each ommission. If a man demands money for this service, the contractor is liable to a penalty of ten shillings. The work must be completed before 10 o'clock a.m. in those main streets which are required to be swept before 9 o'clock. The contents of all public dustbins, wherever situate, are to be cleansed out daily, whatever may be the nature of the contents, under a penalty of twenty shillings. Any man not wearing his badge while at work incurs a penalty of ten shillings. All sweeping of streets, and all the dust and ashes from the houses are to be directly carted away from the City, on a penalty of ten pounds for each cart-load. As to the actual infliction of penalties, evidence of which is of more value than statements of mere liability, it may be mentioned that upon the occasion of an attendance at a sitting of the court of the sewers commission, the contractors who were then summoned for such offences as those here named, were fined in sums which were likely to influence their future conduct for good, and we understood that these cases were not exceptions to the rule.

Notwithstanding the means that are taken to cleanse the streets, the traffic of the city is such as to cause in some places a large accumulation of dirt very early in the day. It consists almost wholly of the droppings of horses, which, whether worked up with water into a thick mud and trodden over the footways or ground to dust, forms a very decided nuisance and a cause of damage to property. In such places the traffic is too great to admit of the streets being readily cleansed during the day. An attempt was made some years since to effect this, by means of men and boys, who kept up a constant collection of the dirt, without allowing it to become spread over the road. This, which was known as the "street-orderly system," was reported upon by Mr. Haywood, who admitted that the streets were kept in a very clean condition, but the cost of the system was very much in excess of the estimate made by its promoters, and it could only be carried on at considerable risk of accident to the scavengers employed. It did not enable the commission to dispense with the regular morning sweeping, and there was besides, this discouraging piece of experience gained by the experiment, the cleaner the pavement was kept the more slippery it became, and the number of accidents to horses was so large as to induce the omnibus proprietors to request that the system might be abandoned. The continuous disturbance of the dust by sweeping during the day was also complained of as producing a greater nuisance than existed under ordinary circumstances.

The principal streets, over 120 in number, are watered twice every working day, from the 25th of March to the 29th of September. The first watering takes place either before the sweeping or after, as may be directed by the inspector, but must be completed before 9 o'clock a.m. The second watering is commenced at noon and completed by half-past 2 o'clock p.m. These streets are also once watered on every Sunday before 10 o'clock a.m. There is a fine of twenty shillings for every street or portion of a street that may have been neglected.

The pavements of some streets, such as Holborn-hill, Ludgate-street, and Skinner-street are thinly strewn with gravel once every day, and arrangements are made in anticipation of severe frost for gravelling the whole of the main thoroughfares at short notice.

Great attention has been bestowed by the engineer upon the various conditions, atmospherical and otherwise, that affect the surface of pavements and the degree of liability to accident. The modes of cleansing, watering, and gravelling are determined by the experience gained in the management of the materials available for use in this country, and by study of the best foreign examples of paved roadways.

The appearance of the streets, both in respect of the materials of which pavements are composed and of the condition in which they are kept, is such that no other district of any size in the metropolis can be brought into favourable comparison with the City in this respect. The main streets in many places are indeed well kept and the condition of others is improving, but the efforts which are now being made by many of the surveyors to the district boards need to be well supported by the members of those boards, in order to substitute for much of the old and uneven pitching of many streets a kind of pavement that can be used with safety, and can without much difficulty be kept tolerably clean. One of the great obstacles in the way of this, which consists in the frequent opening of the streets by gas and water companies, is worthy of particular attention.

We have dwelt upon the question of paving and street cleansing at some length, because we believe its importance to be beyond what is ordinarily seen, and the state of the streets under the Commissioners of Sewers presents what is, upon the whole, a favourable condition of matters. Their officers in the engineering and medical departments have frequently upheld the truth, that the cleanliness of the domestic habits of the people and their health depend in a great measure upon the cleanliness of the streets, and if the success of the system is not complete it is owing in a great degree to the peculiar difficulties of the case in hand.

Gas Lighting.—The state of this question is not so satisfactory as to justify any lengthened notice of it. Three companies have pipage within the City, and complaints of the quality of the supply and its price have led to inquiries and reports upon it. The matter has been for some time in a state of transition, and the final settlement of the question is uncertain, and probably distant. The commission have introduced the practice of burning by metre attached to certain test lamps, and also that of carbureting the gas, and the engineer anticipates considerable gain as well as more complete satisfaction from these changes. With the view of utilising as far as possible the supply that is obtained, he has introduced a new pattern of lamp column and lantern, so designed as to reduce the amount of shadow to a minimum, while space is provided in the base of the post for the metre and carbureting apparatus, with a door for access. These have now been fixed in large numbers as renewals became necessary. A five-light lamp column has also been introduced for use at the resting-places upon the principal crossings of streets. In 1851 the proportion of gas-lights to length and area of streets, area of the City, and number of houses, was as under: their number is since then increased:—

1 lamp to 33 yards of street, or 54 per mile.
1 do. to 281 yards super of street or a square of 16¾ yards.
1 do. to 6 houses.
1 do. to 1097 yards super of the area of City or a square of 33 yards.

For the preservation of the full use of the public way by the public the extent to which householders within the City may enjoy certain privileges over and under the footways that are ordinarily allowed in towns, is defined in standing orders, which are mainly as follows:—

Private lamps projecting over the footway may not exceed 18 inches square, 3 ft. 6 in. in height, or 4 feet in projection from the front of the premises to the outside of the lamp, and the lower part of such lamp must range in height with the public lamps. No French lamp may be fixed at a less height than 7 feet, measured from the pavement to the bottom of the lamp. No person is allowed to erect a private lamp until notice has been sent to the inspector of the district, that he may measure the same and report whether it be conformable to the standing order of the commissioners.

The walls and arches of vaults must be built of good hard stock bricks, one brick and a half in thickness at the least, and the springing walls must be at right-angles with the line of frontage. The top of each arch to be at least 15 inches below the surface of the footway. The external face of the brickwork, or the extreme projection of the front line of the premises, must not be greater than the line of kerb, and must not, in any case, exceed 10 feet, whatever may be the width of the footway. Ovens built beneath vaults must be entirely independent of the walls and arches, and the surface of the crown of the oven must be at least 12 inches beneath the under-side of the arch of the vault. Openings for coals must be made as near the house as possible; the coal plates must be circular, and of not more than 12 inches in diameter, let into rebates in the paving. They must be of iron not less than ¾-inch thick, and deeply chequered on the surface, or if light is desired, the opening between the iron bars must not exceed 1½-inch, and must be filled with glass lenses.

In openings over areas, whether open or glazed, the projection of the gratings or frames from the front of premises (measured at 1 foot above the ground) must not be more than 12 inches, and the length of the grating must not exceed 6 feet. Where more than one of these is permitted, a 9-inch division of hard stone, 9 inches in depth and resting upon brickwork for 6 inches at each end, must be placed. The gratings or frames must be let into the kerbs and run with lead, and must not be made to open—open gratings must be made with frames or borders, the bars running at right angles with the frontage, and not more than 1½ inches apart, they being not less than ¾-inch in width, and of 1 inch sectional area. Glazed gratings must be similarly constructed, but the openings may be 3 inches wide filled with glass 1 inch in thickness. All areas under the footway that are not covered as above described, must be covered with York stone landings 6 inches thick.

Cellar openings or flaps must not exceed 18 inches projection from frontage, nor 4 feet in length; they must have kerbs of hard stone 9 inches upon the face rebated for the flaps, which must be fastened from the inside and must open outwards, these must be made of oakwood only. No staircases may be fixed beneath cellar flaps, and openings to basements are not granted for the purpose of constant access, but for occasionally raising and lowering goods, or removing dust, &c., and they must be closed when not in actual use.

All private drains under the public way are constructed by the contractor to the commission, under the direction of their engineer, and upon payment of the estimated cost.

The rules under which hoards, scaffolds, and shores may be erected have been rendered much more stringent since the passing of the last City Sewers Act. Formerly licences were granted by a different authority, and there was no effectual supervision, the result being that the streets were blocked and disfigured, in many cases for months and even for years, by these obstructions. Even now the system of letting the hoards for advertising is found to be such an inducement for keeping them up beyond the time that is necessary, that very strict supervision is needed. The following are the regulations now in force.—

"That no license for a hoard or scaffold be granted for more than two months.

That no hoard or scaffold project into the carriageway of any street without especial reasons, which should be stated on the license.

That no scaffold be enclosed so as to prevent passengers passing under it; but that the lower stage of all scaffolds be close planked, and proper fans and edgeboards be put out from the same, and any such additional precautions adopted as may in the opinion of the inspector of the district be requisite for the safety of the public.

That no materials be deposited beneath any scaffold, but that if it be necessary for the public safety to inclose a scaffold, or to place materials under it, it shall be licensed as a hoard.

That no hoard be allowed to project further than the feet of such raking or other shores as may be necessary for the safety of the building and of the public, nor for the erection of any new building, more than 6 feet where the foot pavement is wide enough to admit of such projection; nor beyond the extent of the footway pavement in narrow streets, unless in cases of especial emergency, which shall be stated upon the license.

In all cases where it may be safely practicable or needed, a boarded platform, four feet in width, with a stout post-and-rail fence outside, or of such width and dimensions as the inspector of the district may require, be constructed in front of every hoard.

That box hoards be subjects of especial license.

That when licenses are granted for hoards in front of buildings about to be pulled down, proper fans for the protection of foot passengers shall be required to be formed.

That all platforms or projections beyond the line of curb shall be watched and lighted at night.

SCALE OF CHARGE FOR LICENSES.

	s.	d.	
For Hoards.			
To remain not more than two weeks ...	0	6	per foot lineal.
To remain over two weeks and not more than four weeks	1	0	"
To remain over four weeks and not more than eight weeks	1	6	"
For Scaffolds.			
To remain not more than two weeks	0	4	"
To remain over two weeks, and not more than four weeks	0	8	"
To remain over four weeks, and not more than eight weeks	1	0	"

For each Raking Shore.

For four weeks or less, 5s.
For more than four weeks, and not exceeding eight weeks, 10s.

House Drainage.—When application is made by a builder for leave to drain premises into a public sewer, a plan of the property proposed to be drained and a section of the drains, with their connection with the sewer, are prepared to a uniform scale by the engineer, who also makes an estimate of the cost of drainage, so far as it is under the public way, to be paid by the proprietor. A copy of the drawing is furnished to the inspector of the district, who sees that the work is properly executed, and notes upon it any departure from the plan that may be rendered necessary by the nature of the work. This document is then deposited with the records of the commission, and can be referred to at any future time by parties interested in the property. This plan was commenced by Mr. Haywood in 1851, and there are now exact records of the drainage of all the later erections in the City, and of buildings that have been redrained, amounting to a very large proportion of the whole, and which will be extremely useful in all future dealings with the drainage of premises.

Improvements of Streets.—The more extensive improvements, those to main lines of communication, are undertaken by the Corporation under powers granted by parliament and by means of funds provided under the same authority—Cannon-street, Farringdon-road, the modification of thoroughfares communicating with Smithfield, and the proposed raising of the Holborn Valley, have been authorised in this way, and have not been executed by the Sewers Commission. Everyone, however, who is familiar with the City will have noticed the gradual widening of important streets, the opening up of half-closed alleys, and rounding of obtrusive corners, which is going on slowly but with a perseverance that, in the course of a few years, makes important changes in those thoroughfares which most need improvement. These works are carried on by means of funds provided out of the rates and under the powers of the Sewers Commission, who appoint annually an improvement committee to attend to this department. Whenever a building is about to be pulled down for re-erection, the engineer, having notice thereof, ascertains whether it is in the line of any contemplated widening of the street, or whether such widening would be desirable For this purpose plans are from time to time made of localities where improvements are desirable, and are at the same time likely to be within the means of the commission to carry out. A line of frontage is determined upon, the alteration being designed by the engineer and approved by the commission, and in all cases of rebuilding, as before mentioned, negotiations are entered into with the owners for purchase of so much of the property as is required for setting back the building to the line of frontage. If necessary the compulsory powers given by the Paving Act, 57 George III., are exercised for the purchase of the property, the surplus land is let upon building lease, and within a fixed time the ground rents are sold. The large amount of rebuilding that has been going on for some years has enabled the authorities to effect extensive improvements, and when once an improvement is commenced the opportunities for continuing and completing it occur with remarkable rapidity. Within very few years Newgate-street has by this process been very materially widened through nearly its whole length, and the improvement will probably soon be complete. So much of Chancery-lane as is in the City has also been widened, Upper Thames-street from its junction with New Bridge-street is rapidly being similarly dealt with; the narrow thoroughfare at the east end of Tower-street has given place to a wide street; and extensive improvements have been projected and commenced in the narrow part at the eastern end of Fenchurch-street, in Gracechurch-street, and in many other places. Grants in aid of the widening of important thoroughfares have lately been made by the Metropolitan Board of Works, and by the Corporation of London out of its funds. It is much to be desired that the authorities could be moved and encouraged to make similar alterations in cases of well-known obstructions in other parts of the Metropolis, for, while this process has for long been going on in the City, the powers for effecting these improvements have as yet been but feebly exercised elsewhere.

Society for Promoting the Building of Suburban Villages.—A prospectus has been issued preparatory to forming a society to promote the building of suburban villages for the mechanics of the Metropolis. Under the head of Council, it has the names of the Hon. W. Cowper, Mr. H. Pownall, Mr. T. Twining, Mr. H. A. Hunt, and Lieut.-Col. Murray.

HERNE BAY AND MARGATE STATION, KENT COAST RAILWAY.

(*With an Engraving.*)

In the number of this Journal for February last, an illustration was given of the Broadstairs Station, on the new Kent Coast Railway. The accompanying plate is a perspective view and ground plan of the new station at Herne Bay, on the same line of railway. The Kent Coast line is a branch of the London, Chatham, and Dover Railway and, as we stated before, was constructed under the superintendence of Mr. F. T. Turner, C.E. It is open to Ramsgate.

The two stations illustrated in this Journal, Broadstairs and Herne Bay, are similar in character and general arrangement to others recently erected on this branch, which are also from the designs of Mr. John Newton, architect, Salisbury-street, Adelphi, London.

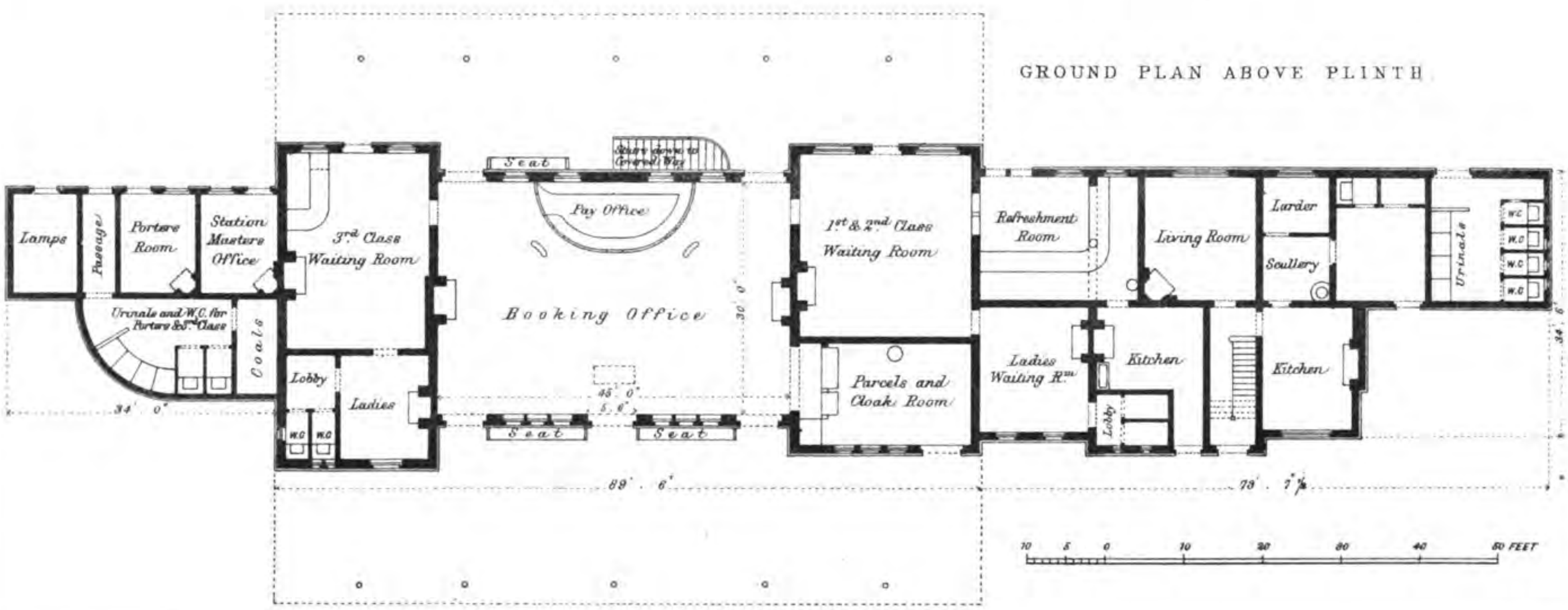
HYDRAULIC WORKS IN THE DOUBS.

It is stated that a very important work is about to be undertaken in the department of the Doubs, in France, with the object of economising and regulating the waters of the lakes of Saint Point and Remoray, and of improving the river Doubs from the lake of Saint Point to the point where the Doubs empties itself into the Saône. The actual level of the lakes is to be lowered, 200 acres of marshy land reclaimed, and the drainage of the entire neighbourhood re-arranged; finally the lakes will be deepened, so as to increase and regulate the water power, which is used by ninety factories of various kinds on the Doubs. The cost is estimated at £96,000, but the value to the existing factories is set down at £24,000, and it is expected that a large number of new works will spring up in consequence of the improvements to be made.

PASSENGERS' SIGNALS TO GUARDS.

There is much truth in the assertion, that if one or two bishops, half a dozen members of parliament, and as many railway directors, were burnt to death in a railway carriage owing to the want of communication between the passengers and the guard, such a calamity would be attended with immense advantage to the railway travelling public. Within a few weeks of such a lamentable occurrence, that which is now considered by railway authorities to be very difficult, if not impracticable, would be accomplished without any difficulty at all, and would be found to be as practicable as the adoption of any of the ordinary safeguards that have been in use since the commencement of railway locomotion. There are now exhibiting at the Polytechnic Institution a great variety of contrivances for increasing the safety of railway travelling, and among them are several modes of making communication between the passengers and the guard, and of communicating from one compartment of a carriage to another. The least feasible of these contrivances would, if necessity compelled, be readily applied to effect the object long desired of being able to communicate with the guard, and the absurd objections hitherto raised to the adoption of such a plan would be easily removed, were a certain number of church dignitaries, legislators, and railway officials, to be immolated for their country's good. In a recent number of the *New York Times*, John Bull is laughed at as "the most obstinately stupid old fool that ever lived," for not having adopted a plan that has been in use in America for many years. "The simple expedient," it is stated, "of running a cord under the roof of the whole length of a train, which has been in use in the United States for twenty years, is still pronounced to be utterly impracticable by the railway authorities of England." It has been stated, as an objection to the plan of a connecting rope or chain, that the connections with the carriages might be omitted to be made, or that they might fail to act, or that the mechanism might become deranged by the vibration of the carriages—anything in short to avoid the necessity of being at a little more expense and taking a little more trouble; but in many of the contrivances shown at the Polytechnic Institution, that objection would not apply, as each compartment of a carriage has an independent signal not connected with the other carriages of the train. The model of a means of effecting communication between passengers, guards, and engine-driver, invented by Mr. Kanig, is a specimen of a

GROUND PLAN ABOVE PLINTH



J. R. Jobbins

HERNE BAY AND MARGATE STATIONS, KENT COAST RAILWAY.

signal of this kind. On the top of each carriage a lantern is fixed, and by pulling a string the light is uncovered in the night time, or a red disc is displayed during the day, so that the guard, looking along the train, would see if any signal were made, and to which compartment of any carriage his attention or assistance was required. The signal once made it cannot be withdrawn until it has been released by the guard, it would, therefore, be impossible for any passenger to give a false alarm without the compartment from which it was given being known. In another contrivance, invented by Messrs. Bernard & Co., a similar mode of making signals is adopted, but the signal is made to project beyond the side of the carriage, and is illuminated at night by a bull's-eye lantern. Messrs. Bernard & Co. comprise in their invention a means of opening the compartments between the carriages to obtain assistance from the passengers in an adjoining compartment; and also a method of ringing a bell in the guard's brake, for long distances, by an electric wire fixed underneath the carriages, and joined by the coupling chains. There are other plans on the principle of calling the attention of the guard by signals projected from each carriage, it being made an essential point in all that the signal cannot be withdrawn after having been made, so as to render the passengers in the compartment whence the signal is displayed answerable for stopping the train. There is one model of a railway carriage, showing a means of allowing the guard to pass from one carriage to another while a train is in motion, as is done on many of the Continental railways, so as to enable passengers to obtain his assistance without the inconvenience of stopping. That might be impracticable in some instances, but there are many railways in this country on which the plan might be adopted, and it would not only afford great protection to passengers, but would avoid the delays occasioned by the collection of tickets. An inspection of the inventions now exhibited at the Polytechnic Institution for effecting communications between passengers and guards in railway trains will prove that it is not from lack of contrivances to accomplish the object, that it has not been adopted on all the railways of this country. The objection, that if such a means of communication were established it might be abused by foolish, or timid, or drunken passengers giving unnecessary alarms, is of very little weight. The infliction of a heavy fine or a few months of solitary confinement in two or three cases, would soon put a stop to such an abuse of a means of safety that no railway passenger should be without.

There are exhibited also in the same place several other valuable means of adding to the safety of railway travelling, by improved modes of making signals along the line, of stopping railway trains, and preventing them from running off the rails, but we must reserve the notice of them for another occasion.

ARCHITECTURE IN MANCHESTER.

The city of Manchester, with its surrounding manufacturing towns, has little in the way of architectural antiquities to boast of; and still less of rural scenery, or indeed of the picturesque in form or colour, with which to attract the London student, setting out on his yearly sketching tour. It may be said to be a disagreeable city to visit; and the same thing might be predicated of most, if not all of the towns which immediately surround it: such as Oldham, Bolton, Ashton, Bury, Stockport, Hyde, and their respective off-shoots. Many of these towns, indeed, occupy sites that in years gone by have been unquestionably beautiful; but the advent of the cotton trade has choked up the once pleasant valleys with huge masses of silk and cotton mills, dye houses and foundries, monotonous in form, and monochromous in hue; whilst everywhere in immediate contact with their district, or even within miles of their site, the stunted, blackened vegetation gives token of the blighting influence of the tall chimneys piercing the air, and emitting what the late Cardinal Wiseman in a poetic mood was pleased to designate, "their waving pennons of smoke." And yet, with all this and much more of the disagreeable—the frequent falls of rain; the redundant artisan population; the dull murky atmosphere, and the blackened rivers, Irwell, Irk, and Medlock, on whose thick scum, if we are to credit Lord Robert Montagu's statement, the very birds can walk along—there is, perhaps, no town or city in the country whose centre and suburbs can boast of better modern edifices than Manchester.

We once heard an amateur describe Manchester as "a city of handsome doorways;" and it well deserves the appellation. It is quite refreshing to any one accustomed to the wearisome builder-built doorways of London, to pass along the main streets of Manchester; and to everywhere recognise the pencil of the architect of some sort, in these features of the city. If our readers search the central streets, "where merchants most do congregate," they will find many examples of these architectural frontispieces, well worthy of a place in their sketch-books. These frontispieces are most common to the warehouses, &c. in the city; but in its outskirts many of the suburban villas also will be found rich in that hospitable feature, a handsome doorway. Hospitality, by the way, is a distinctive peculiarity of Lancashire life; and this virtue the ample, well-designed doorways of Manchester do very adequately symbolise. They have a *siste viator*, "cut and come again," look about them, utterly wanting in the doorways of the Metropolis: one may indeed say of it, there are very few external doorways of any consequence in or about the Metropolis, that can offer the visitor a guarantee of two properties, seldom lacking to the doorways of Manchester, viz., truthfulness of material, and the veritable sign manual of the professional architect. When we speak of this latter, we assume, as a matter of course, an architect of any kind is always better than no architect at all—the usual alternative of our wretchedly crude and uncouth London doorways.

Nothing can be more antithetical than the architecture of Manchester—taking the city and suburbs as a whole—and the "architecture" so called of London and its suburbs, taken on the whole. The antithesis does not owe its rise to any want of architectural talent in the Metropolis; but to the presence of a field for that talent in Manchester, and the almost general absence of it in London. We fear it is a permanent evil: the tenure of land in Manchester is usually 999 years; a term which at once sweeps away the need of those odious surveys for repairs and dilapidations so common to an architect's practice in London; and compels the capitalist or landowner of common sense to call in an architect to devise the structure that is to be his and his heir's for so long a period. No man sits down in Manchester to build a house, or a warehouse, a bank, an insurance office, or even a shop of any pretensions, without consulting an architect; and when he does it, with his 999 years' tenure in view, it never occurs to him to suggest to his architect such flimsy materials as Roman or Portland cement. He directs him to face his building (if not with ashlar stone) with the choicest brick, which is usually of a rich red colour: and to work out the architectural embellishments or "dressings" with durable stone, from Huddersfield, from Colne, from Hollington, or from Leeds, and its famous quarries thereabout. Hence there is a reality, most pleasing to the eye of the intelligent architect, about most of the buildings of Manchester.

There is another peculiarity about the architecture (or rather the buildings) of Manchester, which makes this city a very paradise of architects. The buildings all rise from the ground without the intervention between their fronts and their designer, of an external scaffold: the workmen are in the habit of working, as the phrase is, "over hand;" and the designer can foresee the effect of his details as the work goes up. Lofty and architectural as are the tall factory chimneys immortalised by the deceased Cardinal aforesaid, they all rise into the air, some two and some three hundred feet high, without a vestige of external scaffolding; and in this way too up go the steeples with their lofty spires. Thus the architect — to say nothing of his "facile ascent" to the summit of his edifice—always a desideratum to an architect, who does not every day ascend ladders, like a bricklayer—has a chance of day by day seeing the effect of his design in process of execution; a boon quite denied to a Londoner, who never, till the scaffold is struck and the eye-sore is past remedy, can discern the defects of his details.

Many of the public buildings of the city have been already described in previous numbers of this Journal, and notices of the most remarkable ones — the Assize Courts, the Town Hall, Royal Institution and Athenæum, the Royal Exchange, Royal Infirmary, Free Trade Hall, and Mechanics' Institution, may there be found. Two of these structures, the Royal Infirmary, and the Royal Exchange, have undergone considerable modifications by new designers, since they were first built by the old ones; and, being of Classic character, have not, as might be expected, that congruity which edifices of their class, that have not been subjected to this second-hand process, ordinarily exhibit. The Royal Infirmary was originally a dingy brick structure, of astylar design, and has for many years past been undergoing, under the direction of Mr. Lane, a kind of semi-periodical casing with stone, and bedizening with Ionic columns and pilasters, of that severe and tame adaptation of the Greek style so observable in the works of Sir Robert Smirke. And yet the site upon which the Infirmary stands may be considered one of the best in England, if not in Europe. There has been for several years past a project on foot for removing the Royal Exchange to this admirable site, taking down the Infirmary, and erecting a new Exchange in its place. Certes, it will take a very handsome edifice to do justice to so fine a position.

The existing Town Hall too is likely to be abandoned, and a new one is projected. The present edifice is a very superior building to the Royal Infirmary; being a Classic structure, bereft of its crowning sculpture (more's the pity), but designed by no feeble hand, with great spirit and ability. Its large room, though now too small for the busy city, has been often commended, and deservedly, by eminent writers on architecture. Should a new town hall be erected elsewhere, it is to be hoped that the present one may not be taken down, or converted to any ephemeral commercial use; but reserved for some permanent municipal purpose, which will admit of its charming façade remaining undisturbed and inviolate. The Town Hall is not by any means a large building, nor is its site an advantageous one, but it has about it an undeniable air of monumental grandeur; is at once, so far as its order of achitecture is concerned, a valuable copy of an exceedingly interesting example of the Ionic order—that of the Temple of Erectheus, at Athens—and a highly original composition; bespeaking a profound knowledge not simply of Greek detail, but of perspective grouping and *chiaro oscuro* on the part of its designer. In the same street (King-street) stand two commercial buildings, that will claim the attention of visitors. They are the Royal Insurance office, an Italian edifice by Mr. Walters, and the Liverpool and London Insurance office, by Mr. Waterhouse. The latter is a Gothic structure, and, like its Italian rival, is constructed wholly of rubbed stone; but is destitute of the advantage of a corner site, which the former possesses. The two buildings are well seen in contrast from the opposite side of the street; so that here occurs a very fair test of the relative value of the two styles of architecture. Mr. Walters is well known as a skilled master in Italian *cinque cento* composition; and Mr. Waterhouse—the architect of the New Assize Courts, so highly commended during the lords debate on the new Courts of Justice —may be said to be a Gothic "foeman," younger, indeed, but worthy in every sense of that gentleman's "steel." The result, we should say, is wholly unfavourable to the Italian school of my Lord Palmerston; and even his lordship would, we think, admit the fact, were he to view these two buildings in contrast.

These two edifices are interesting by reason of their juxtaposition, the identity of their uses and constructive material, and the fitness of their respective architects to do battle for their favourite styles; but as their elevations may be seen engraved at every railway terminus in England, they are too well known to require any further architectural description here.

Comparisons are proverbially odious; and yet, speaking of Manchester commercial buildings, one cannot avoid a comparison between another of Mr. Walters' buildings (the Manchester and Salford Bank, at the corners of York and Morley streets) and "all Lombard-street." Large banks and insurance offices are rising in Lombard-street just at this time; but the greatest of these efforts in brick and mortar—and that, we humbly submit, is the bank of Messrs. Robarts, Lubbock, & Co.—is a mere pigmy in comparison with this Manchester bank; whose massive unbroken stylobate, some 8 feet high, would, drawn out to its full length, go far towards reaching half way down one entire side of Lombard-street. It is one of the few buildings of Manchester occupying a site adequate to its pretensions: is by no means equal in merit, as a design, to others of Mr. Walters' works, but (albeit it is void of any commendable originality desirable in so large a work by so capable a hand) the design is wholly free from defects of detail and composition. Mr. Walters might have made more of his opportunity: many an architect of ability by aiming at more would have done less, and peradventure have spoiled the whole affair; as may be seen in a well-known warehouse of even more Brobdignagian proportions, not far away from this bank.

This famous warehouse, a perfect marvel in its way of vastness and elaboration, if not of good taste, brings us to notice another large commercial building, a vast pile of warehouses at the end of Aytoun-street, Piccadilly, designed by Mr. Corson. Here truly is to be seen no great amount of elaborate embellishment, nor even a very plentiful use of cut stone; but there is something far rarer, and for worthier of one's commendation: there is the evidently thoughtful study of the architect, which has made the most of all available means. Wall space, and windows, offer indeed but simple elements for the designer; but these, with a few horizontal bands, Mr. Corson has so manipulated as to produce a structure of singular excellence. His clients, like many other Manchester men, with "plenty of brass," have given him an element of the sublime—vastness—ready to hand; and Mr. Corson has had the good sense to let well alone; and to modestly confine his efforts to the superadding to that desirable element a few well-proportioned, well considered, simple, and unobstrusive features; whilst many another architect would have overlaid his building with pretentious details, and have marred the entire composition. The building has, we believe, been erected for Messrs. Barber, and is one of the finest, if it be not the very finest, of the warehouses of Manchester.

STRUCTURES IN THE SEA, WITHOUT COFFERDAMS.

By Daniel Miller.

(*With an Engraving.*)

The following paper* treats of the various methods of constructing the foundations of quay-walls, piers, or breakwaters, for the formation of docks and harbours in deep water; it describes works of this kind carried out on principles different from those usually practised; and points out the further application of these principles to other works of a similar nature.

The formation of these works has usually required the adoption of very expensive means; and an easy and economical mode of building such structures, so as to combine the various conditions necessary to insure solidity and capability of resisting the mechanical forces to which they are subjected, and also the destructive action of exposure to the elements, the boring of marine worms, or the corrosive action of salt water, has been hitherto a desideratum.

Several methods of founding works in deep water are at present practised; but there are objections to most of these systems, arising either from their expensive nature, or from defects in the durability of the structures. The plans which have chiefly prevailed are—founding on piling carried up to about the level of low water; constructing within caissons or cofferdams; or building under water by means of diving apparatus.

The first method has serious defects, both in deficiency of strength and of durability, as the piling is often insufficient to resist the lateral pressure from behind the wall, and the heads of the piles being exposed to the alternate action of air and water soon decay, when the weight of the wall above rapidly completes the failure of the whole structure. Of course where there are marine worms this mode is quite inapplicable. Instances of the failure of such works will occur to many. Referring to the river Clyde, for example, nearly all the older quay-walls of the harbour of Glasgow were built on this principle, and have given way from the decay of the piles, or have required very expensive repairs to keep them up; and at Port Glasgow Docks, the walls, which were also built on that system, gave way from the lateral pressure forcing them out, shortly after completion, greatly to the injury of that port.

The most usual mode adopted, where works of great solidity are required, is to resort to cofferdams, and to pump out the water from the enclosed space, so that the foundations and walls may be constructed as on dry land. This is certainly most effectual, but it is at the same time generally expensive, and is often not unattended with danger. In many cases, too, from the nature of the strata, it is almost impossible to form an effective cofferdam. The construction of cofferdams, moreover, frequently requires great engineering skill, besides involving vast expense; and when it is considered that they are only wanted for a temporary purpose, it must be conceded that it is an object of great import-

* From the Minutes of Proceedings Inst. C.E.

ance to devise some mode by which their use can be obviated, and solid and durable works can be executed without their aid.

The system of building under water by means of diving-bells and diving-dresses has been practised to a considerable extent, and the improved apparatus now used gives great facilities for this kind of work; but it is only applicable under particular circumstances, and it is also costly, besides being liable to cause delay in the progress of the work. The Dover Breakwater, at present in course of construction, is an example on a large scale of this mode of construction, but it is also an instance of the vast sums which may be expended on this system.

In bridge building, a great innovation has been made in the construction of the piers without the aid of cofferdams, and the French engineers have been, until lately, in advance in this mode of constructing such works. The plan they pursue was introduced by Vicat in 1813; it consists in forming enclosures of close piling, or "caisses sans fonds," of the shape of the pier, up to about low-water level, and filling in with hydraulic concrete, or beton, on which the upper part of the piers is built in the usual manner. Some important bridges in France, and many of those across the Seine at and near Paris, such as the Carrousel, Jena, Austerlitz, Alma, and Asnières, have the piers formed in this way without cofferdams. These works of the French engineers, however, being in some instances a combination of timber and concrete, cannot be said to possess substantiality and durability, and a change was necessary, in order to enable them to compete with stone structures built in the usual manner. The modes recently adopted in constructing the piers of the Westminster and the Chelsea bridges without cofferdams, have effected this, and these works are instances of successful departure from stereotyped rules, and of the application of scientific principles in the practice of bridge building.

Application of Concrete.

In these modes of construction, beton or hydraulic concrete has played an important part, and it also forms a leading feature in the plans for marine works afterwards to be described.

This valuable compound, though employed in Roman and mediæval times, was allowed to go out of use, and since then it has not, until recently, been much recognised as a constructive material by the engineers of this country, who have, for marine purposes, placed their faith chiefly in works of cyclopean masonry, constructed within cofferdams, or built under water by the diving-bell. The French engineers deserve the credit of having been, for a longer period in modern times, alive to the value of beton, as an important auxiliary in hydraulic works.

For some time, however, its value has been more appreciated in this country as a substitute for masonry, and it has been employed in some important works. Still, its use is chiefly confined to forming a homogeneous and monolithic bearing stratum for foundations, and not, properly speaking as a constructive material, to which latter purpose it is more especially the author's object to direct attention. In particular, there are but few examples of the application of liquid concrete, deposited and allowed to set in the water, in the construction of submarine works.

There are three modes in which concrete may be applied for constructive purposes,—building it in mass, and allowing it to set before water has access to the work, as has been adopted in the construction of the walls of the Victoria Docks, by Mr. Bidder, and in those of the London Docks, by the late Mr. Rendel; preparing it first in blocks, and allowing it to harden before being used, as employed by the late Mr. Walker at the Dover Breakwater, and by Mr. Hawkshaw for the new sea forts for protecting the arsenals of Plymouth and Portsmouth; and depositing it in a liquid state, and allowing it to set under water, as practised upon a gigantic scale by M. Noël, in the construction of the large government graving docks at Toulon. In the later case hydraulic concrete has been deposited in a liquid state, in the sea water, at a depth of about 40 feet, forming a vast rectangular trough of beton about 100 feet wide, of the length of each dock respectively, and with walls and bottom about 16 feet thick. After the beton had set, the water was pumped out from the interior, an inner lining of masonry to form the altars, stairs, and floor was built, the caisson put into its place, and the concrete side of the trough at the entrance having been removed, the dock was complete.

The facilities for making beton or hydraulic concrete, which has the invaluable property of setting under water, and of thus forming an artificial rock or stone, are very great; as it may be formed either from the naturally hydraulic limes, the artificially hydraulic limes or cement, or from the rich or non-hydraulic limes rendered hydraulic by the admixture of other substances, such as pozzuolana, minion, or iron-mine dust.

The beton made from the naturally hydraulic limes, which are found extensively in this and other countries, is the most to be depended upon. The blue lias in England, the limestone of Arden (found near Glasgow) in Scotland, and that of Theil in France, are good specimens of their kind, possessing in an eminent degree the property of setting under water. Of the Arden lime, the author and his partner have had abundant experience in the dock works at Glasgow, Greenock, and other places. As to the blue lias, its extensive employment in the docks at Liverpool, London, and other important works throughout the kingdom, is proof of its good properties. The hydraulic limes of France have been still more severely tested, by their application for the formation of the large concrete blocks used for the protection of the seaward side of the French breakwaters. It may be useful to mention, for comparison, the proportions of some of the concretes made from these various limes. The Arden lime concrete, employed by Messrs. Bell and Miller for the foundations of the large graving dock at Glasgow, was composed of one part of ground Arden lime, one part of iron-mine dust, one part of sand, and four and a half parts of gravel and quarry chips. The lias concrete, used at the recent extension of the London Docks by Mr. Rendel, consisted of one part of blue lias lime to six parts of gravel and sand. The proportions adopted for the blocks of the Mole at Marseilles, were two parts of broken stones to one of mortar, the latter being composed of three parts of Theil lime to five of sand.

A knowledge of the mode of composing artificial hydraulic limes is of great importance, in situations where natural hydraulic limes are not easily procurable. Smeaton was the first to point out, that it was to the clay or silicate of alumina, in the composition of the hydraulic limes, that they were indebted for their peculiar property. Subsequently the able researches of Vicat showed, by actual experiment, how all the rich or non-hydraulic limes might be rendered eminently hydraulic, by burning them with a certain proportion of silicious clay. Indeed, to Vicat is due the credit of having reduced the knowledge of limes to a system, and of having shown the practical application of concrete as an eminently constructive material. The excellent artificial cements now manufactured are most valuable to the engineer; and the concrete made with Portland cement can hardly be surpassed. That used at the new Westminster Bridge is harder and more compact than the greater number of building stones, even where put down in the bed of the Thames, and where it is exposed to the running stream. Portland cement concrete is also extensively used for the artifical blocks, weighing from 6 to 10 tons each, which form the hearting of the breakwater at Dover and that at Alderney, the proportions being one part of cement to ten parts of shingle.

Some substances, such as pozzuolana—a volcanic production found chiefly in Italy—have, in consequence apparently of silicate of alumina being predominant in their composition, the property of giving hydraulic qualities to the rich or non-hydraulic limes. It is of these that the concrete is made which has long been used for marine works on the shores of the Mediterranean; and indeed, the piers at some of the Italian ports have been constructed almost entirely of hydraulic concrete. The author had lately an opportunity of examining, at Genoa, the extension of one of the moles of the harbour, the inner side of which has a vertical wall. The latter was in process of being constructed under water entirely of pozzuolana concrete, simply thrown into the sea from baskets carried on men's heads, a hoarding confining it to the shape of the wall. In a short period it set quite hard, so as to enable the upper part of the wall, which is of stone, to be built upon it. The outer side of the mole, which had been previously made, was formed by stones deposited "à pierre perdue." Though the depth of the quay wall was not great, this shows the confidence which the Italian engineers have in concrete applied under water in a soft state. The piers of the new basin constructed by the Austrian government at Pola, in Istria, are also formed, in a similar manner, of concrete confined between rows of timber piling.

But perhaps the most striking application on a large scale of pozzuolana concrete is in the great mole which protects the port of Algiers. To form the mole, blocks of beton of immense size, so as to be immoveable by the force of the sea, were employed. Some of these were formed *in situ*, by pouring the concrete into large timber cases without bottoms, sunk in the sea in the line of the mole. Other blocks of a smaller size, though upwards of 30 tons in weight, where made on shore, being moulded in strong wooden boxes. After the beton had set, the boxes were removed, and the blocks were launched into the sea to find their own level. The beton for the blocks *in situ* was composed of one part of rich lime in paste, two parts of pozzuolana, and four parts of broken stone; that for the blocks made on shore was formed of one part of lime in paste, one part of pozzuolana, one part of sand, and three parts of broken stone. These blocks set sufficiently hard in twenty-four hours to resist the shocks of heavy seas, and the mole now stands firmly, instead of being, as it was when formed of loose blocks of stone in the time of the Moors, nearly destroyed every winter.

The French engineers have shown great boldness and skill in the application of beton, as exemplified in the Pont de l'Alma over the Seine, the arches of which, as well as the piers, are formed of rubble concrete; in the new graving dock at Toulon, before alluded to; and in the formation or protection of breakwaters by enormous artificial blocks of beton, as carried out at Marseilles, Cherbourg, La Ciotat, Cette, Vendres, Cassis, and Algiers. A short time ago, when the author inspected the mole or breakwater which encloses the harbour of Marseilles, he found the huge rectangular concrete blocks, weighing upwards of 20 tons each, by which its seaward side is protected on the "pierre perdue" principle, perfectly entire and sharp in their outline, though they had been exposed for many years to the action of the sea. Any one standing upon that mole, and witnessing in a gale the heavy seas breaking with tremendous force on these concrete masses and recoiling harmlessly, could have no doubt as to the efficiency of concrete as a constructive material.

Hydraulic concrete, to be effective, requires care and attention in its manipulation, and in the regulation of the proper proportions of its materials. Any failures must have arisen from inattention to these, or similar points, as there is ample experience to show that, when properly made, every confidence may be placed in its strength and durability. Even where stone is abundant, this material may be often employed with economy and advantage; but where stone cannot be obtained, the importance of being able to form an effective substitute out of materials of so little value, and so widely distributed, can hardly be overrated.

Construction of Dock and Quay-walls without Cofferdams.

Though so much has been effected in bridge building, little has yet been done in founding and constructing quay-walls, piers, or breakwaters in deep water, of a solid and durable character, without the aid of cofferdams, diving apparatus, or other means equally expensive. The author has, for a considerable period, devoted his attention to this subject; but it is only recently that he has had a favourable opportunity of putting his ideas into practice upon a large scale.

In sea water the engineer has to encounter enemies which do not exist in fresh water, or at least only to a trifling extent. The "teredo navalis" and other worms quickly destroy timber, and the corrosive action of the sea water, and other peculiar properties, have a prejudicial effect upon iron. In consequence of these deteriorating influences, these materials have not hitherto been much employed in sea works, where durability is essential. There is no doubt, however, that they may be employed with advantage, if protected from the destructive action alluded to; and whatever materials may be used, it is desirable that the surfaces exposed to the sea should be of continuous stone-work, or other material capable of resisting its effects.

As engineers-in-chief for the Albert harbour at Greenock, the author, and his partner Mr. Bell, have had an opportunity of introducing the new system there adopted for the construction of sea-walls and quays in deep water, without the aid of cofferdams, by which a large saving is effected, and works of great solidity and durability have been secured.

The accommodation for the loading and discharging of the shipping of Greenock consists of three open tidal docks or harbours, the most recent having been constructed by the late Mr. Locke, M.P. Extensive schemes for wet docks have been proposed at different times by several engineers, particularly by Rennie, Telford, and Walker and Burges, but hitherto no wet docks have been constructed, as it has been considered that the moderate range of the tide—from 8 feet to 10 feet—does not render them indispensable, and the trade is found to be efficiently worked by the present system. In the additional accommodation in progress, the system of harbours is adhered to, though provision is left for conversion into wet docks, by the addition of locks and gates, should this at some future period be deemed advisable.

The new works are situated on the west side of the town, and in order not to interfere with valuable shore ground, they have been projected almost entirely beyond the high-water line into the sea. The depth of water at the outer line being considerable, the amount of excavation required in the interior is comparatively little. The outer sea pier, according to the plan proposed by the engineers, will enclose a large extent of shore as well as the Bay of Quick, and when carried out to the full extent, will be upwards of 3000 feet in length. Within this area there will be space for two harbours, each 1000 feet in length, 15 feet deep at low-water, or 25 feet at high-water, with entrances 100 feet wide. There will also be ample room for the construction of graving docks, for the storing of timber, and for the erection of sheds. The two harbours are connected by a lock 350 feet in length, by which one of the harbours can be converted into a wet dock, with a depth of 25 feet, when required; and a graving dock is contemplated being constructed in connexion therewith. It is only intended, however, in the mean time to execute about one-half of the sea pier, and to form one harbour or tidal dock, which will be called the Albert harbour, leaving the prosecution of the other works till the growing trade demands further accommodation. This, from the present increase of shipping, will be at no distant period.

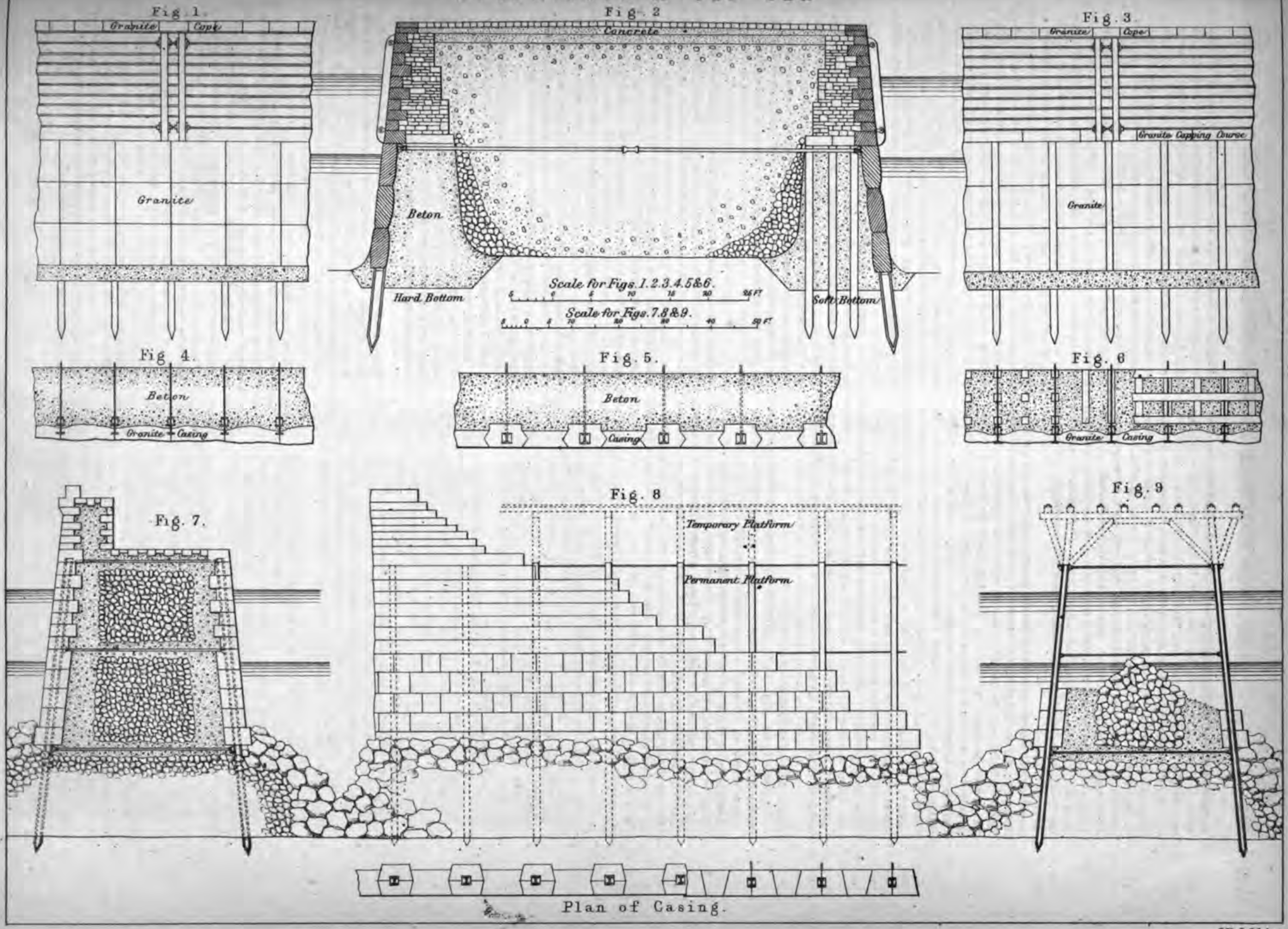
The depth of water along the line on which a cofferdam must have been constructed, had such been contemplated, is in many places nearly 30 feet at high-water; and taking into account the length, and that it must have been of strength sufficient to resist the storms of winter, it could hardly have cost less than £50,000. Besides the great cost of a cofferdam, there was another difficulty, as, owing to the line of the proposed new pier being close to the edge of the deep-water channel, it would have been necessary to project the cofferdam so far into the channel, as to have formed a serious interruption to the traffic. In consequence of these difficulties, and from considerations of economy, it had been the intention of the trustees to use timber for the outer piers of the harbour, and the engineers were instructed to make their plans accordingly. It was the opinion, however, of the author and his partner, that in a situation where the sea-worm is very destructive, the work ought not to be constructed of such a perishable material, and that it was quite possible to build a solid structure, so as to avoid the difficulties referred to, in an economical manner. In order to effect this, they proposed to construct the outer pier and quays forming the seaward side of the dock without cofferdams, so that the pier might itself serve as a cofferdam for the interior operations in the harbour which would afterwards be required. This seaward pier is 60 feet wide at the top, having quays on both sides.

The mode in which the work was designed was, to form the walls under low-water of a combination of cast-iron guide piles in the front, with a continuous stone facing slid down over and inclosing these, and of concrete backing deposited in a soft state, all of which could be accomplished from above the water line. Timber bearing piles were to be used in the body of the walls where required, and the upper part of the walls from the low-water line was to be carried up of masonry in the usual manner. See the Figs. 1 to 6 on Plate 11, where Fig. 1 is an elevation of part of pier at low-water. Fig. 2, a section of the sea pier. Fig. 3, an elevation of part of pier. Fig. 4, a plan of part of pier at low-water. Fig. 5, a plan of casing. Fig. 6, a plan of part of pier at low-water. Fig. 7, a section of breakwater with parapet. Fig. 8, breakwater. Fig. 8*a*, plan of casing. Fig. 9, section of permanent framing and temporary platform.

This plan was felt to be so novel, particularly with regard to the application of the concrete, that though the trustees as a body had the greatest confidence in the engineers, they considered it to be their duty, before proceeding with the work, to fortify themselves by having the opinion of another engineer. Accordingly, Mr. Thomas Page, C.E. was consulted, who fully satisfied them as to the efficiency of hydraulic concrete applied in the manner proposed, and otherwise confirmed the soundness of the principles upon which the works were designed. At his suggestion, granite from the Ross of Mull was substituted for freestone, for the stone facing under the low-water line, as it could be obtained in large blocks at a moderate price; he also recommended that the timber piling should be dispensed with, but the nature of the bottom has hitherto not allowed this to be carried out to any great extent.

(To be continued.)

STRUCTURES IN THE SEA



J.R Jobbins

CHURCH BELLS: THEIR ANTIQUITIES AND CONNEXION WITH ARCHITECTURE.

By Rev. J. H. Sperling, M.A.*

So much has been said and written of late years on Church Bells, that, notwithstanding this is the first time the subject has been brought before the Architectural Institute in the shape of a lecture, it is by no means easy to discourse upon it with any charm of novelty to the scientific audience which I now have the honour to address, many of you being probably as well up in the subject as your lecturer. Campanology, however, is a science (I use this term advisedly) which most appropriately holds a place in an association like our own, whose object is to develop and enunciate the close and inseparable connexion of high art with the Catholic faith, for no musical instrument has ever exercised so great an influence upon architecture as the church bell. To it we owe the most striking external features of our churches, whether in the varied groups of the many-towered city, or the country spire, pointing amidst the trees to the skies, or rearing itself heavenward like a ladder of fire, as seen in the horizontal rays of the rising or setting sun against the tame horizon of the fen country of East Anglia. Then, again, there are the hundred different forms of cot and gable which crest the humbler village church.

Sometimes we find large towers standing altogether detached from the churches to which they belong; the campanile at Chichester is a well-known example to most of us. Canterbury and Salisbury also yielded similar examples, the latter having been wantonly destroyed almost within the memory of those still living. Beccles, in Suffolk, is another notable example; so is Ledbury, in Herefordshire, and West Walton, in Norfolk, the latter forming a noble entrance gateway to the churchyard. I might name a dozen smaller ones. Now these towers were not built for mere fancy or picturesque effect, but to contain heavy bells, the vibration of which would have a gradually ruinous effect upon the general fabric of the churches to which they belonged, were they an integral portion of them. For the same reason the central towers of minsters and other large churches were intended to be lanterns proper, and not campaniles. The experiment was tried in a few instances, and great was the ruin that followed where the bells were at all heavy, as at Winchester and Ely. Bell-towers proper were invariably as little connected as possible with their churches. With the exception of Hereford, which fell down; Ely, which never had a large bell; Wimbourne Minster; and two or three other examples, we never see a minster proper even with a *bonâ fide* west tower; and yet we may be sure that their architects would most gladly have had them could it have been possible, for the greater space allowed for fenestration permitted by their absence is no equivalent (viewed internally at least) for the noble western arch which their existence would have afforded. The tame internal western perspectives of Winchester or Norwich will hardly bear comparison with the western tower churches, even of the smaller type of Boston or Wymondham. Bell-towers were placed either westward of the aisles, or on one side of them, as at Exeter, on purpose to lessen their connection with the building, and guard against the ruinous shake of vibration. A virtue may, indeed, be said to have arisen out of the necessity, and an elegance and dignity to have been conveyed externally, by the double western tower; but this must, I think, be viewed as an effect necessitated by a cause, rather than as an original creation unfettered by circumstances.

Whether you agree with this theory about western towers or not, we shall all I think, concur in this, that our forefathers did not build towers and spires only to put into them the very small and ill-sounding article, the click of which is a standing nuisance to the western half of the Metropolis. Most old churches were furnished with such bells over and above the chiming bells; they occupied either the eastern gable of the nave as a sanctus bell, or they hung in some picturesque little louvre, outside the tower or spire. Specimens of this latter treatment may be seen at Hadleigh, in Suffolk; Ichleton, and Hinxton in Cambridgeshire. Sometimes they hung in the weather-boarding of the belfry windows; but this latter arrangement is much more common on the Continent than in England, whole chimes being thus exposed to view in the belfries of the South of France, Italy, &c. Though no larger than the model call-bell of a London district church, their tone was sweet and silvery. Neither, again, did our ancestors build their towers as a very convenient smoke-flue, as was so common twenty years since, till we were bold enough to venture upon the good, open, honest, undisguised chimney. I would urge upon all connected with church building that the object of towers is to contain bells, spires being merely their ornamental capping; and that, unless there is a good and reasonable prospect of more bells than one, the money would be far better expended in adding height and dignity to the interior, which in a town church, where we have now to contend with the rapidly-increasing bulk of secular architecture, is becoming more than ever a vital point.

However, we must fall back upon the bell itself. In the first place, it is a satisfaction to be able to claim an unmistakably Christian origin for an instrument which has laid so mighty a hold upon ecclesiastical architecture. The earliest names for bells —"nola" and "campana"—would seem to point to Nola, in Campania, as their birth-place, and the fifth and sixth century as their earliest date. A favourite and expressive Mediæval name for a church bell was "signum," I not long ago read in one of the newly-printed Record publications, but I have unfortunately mislaid the extract, giving names and dates; but the fact is this, a certain Irish bishop, who was also suffragan to the see of Worcester, was sent over to Tewkesbury, to consecrate two new bells for the abbey church in that town, and the legal term employed for them is "duo magna signa."

The very earliest bells were probably mere sheets of metal curled into a circular shape, and riveted together at their junction, the top being flattened in. These were struck on the outside by a hammer, having no connexion with the bell itself. This, of course, produced no very exquisite tone. Once started, bells soon developed into shape and size somewhat analogous to those now in use. The art of working and fusing metals together was a very early invention; and the sister one of melting and casting not long in following. We know that both tin and copper ore were worked in Britain during the Roman occupation of the island, probably still earlier in more civilised Europe. There is no reasonable doubt that a bell, or even bells, in important places, formed a portion of the furniture of every church before the Norman Conquest. Judging from the vast size of Norman towers, I think it highly probable that church bells had at that time reached their largest dimensions in this country, and also attained a perfection not since surpassed. The fact of no bells of ascertained Norman date remaining at the present day, when we consider the hundred and one different accidents to which such an instrument is subject, is no proof in the case whatever. Considering the bell as an instrument of percussion, it is only a cause of wonder that so many examples, even of the thirteenth, fourteenth, and fifteenth centuries, have come down to us uninjured. Then, again, there are other causes for change besides breakage: fashions as to shape and size and number changed also, just as churches themselves were always more or less under alteration and supposed improvement.

[The lecturer here read a short MS. account of the bells in Canterbury Cathedral (Canterbury, vol. i. p. 91, No. 453) as one example out of many of this constant change; and though perhaps churches of less note and smaller revenues were favourable exceptions, still this rule of change remained in a very large percentage.] From this account you will see, amongst other things, that bells, as I said before, attained very large dimensions in the eleventh and twelfth centuries. They so continued till the Reformation; soon after which the art of change-ringing coming in, completely overturned the existing order of things. Under the old system bells were few and heavy, dignity of tone and solemnity being the main desideratum, and, as they were only chimed, lightness was not an object. Cathedral churches were not allowed to possess more than five or seven bells, and these often not placed together for simultaneous use; collegiate and parish churches, not more than three besides the sanctus bell. There is a curious injunction extant relative to the village churches on the coast of Kent and Sussex, to the effect that they should not possess more than one bell each, lest they should present an object of plunder to opposite neighbours; church bells not being readily movable like plate, vestments, and lighter articles. It is curious that to this day the same rule seems in force, for in no other district in England are there so many one-bell churches as along that coast, while directly we get a few miles inland peals of three and five are the prevailing number.

The oldest bells that have come down to us bear simply the

* Paper read at the Architectural Museum.

names of the saints to whom they are dedicated—the tenor, or heaviest bell, usually representing the patron saint of the church; the others, for the most part, the names of those saints who had altars below: and I very strongly suspect that each bell was tolled for mass at the altar of its own dedication. This is a point I should much like to have cleared up by some one learned in Mediæval ritual. At present I would only throw it out as a probability, from the fact that, out of a number of such cases which I have examined, I have found a considerable balance in favour of the connexion between the names of bells and the records of altars so dedicated. At Durham, for instance, there were four great bells in the Galilee tower, and three smaller ones in the lantern tower, dedicated, the largest to St Cuthbert, another to Christ and the Blessed Virgin, a third to St. Margaret, another to St. Benedict, another to St. Michael, another to St. Oswald, another to the Venerable Bede; all of whom were commemorated either in the nine altars or elsewhere in the church. I will take one other example. At the church of St. Bartholomew the Great, Smithfield, now undergoing its interesting restoration, is a little peal of five bells, dating from the close of the fifteenth century. Here the treble is dedicated to the patron saint, the others to St. Katherine, St. Anne, St. John the Baptist, and St. Peter, each dedication ending, as was usual at that period, with an "*ora pro nobis.*" Possibly there may be documents yet remaining which may connect this peal with some subsidiary altars in that church. If some of you do not mind doing a little chimney-sweep's work, you will be rewarded for your trouble by personally inspecting these bells; also a similar peal of three in the adjoining church of St. Bartholomew the Less. These are almost the only ancient bells remaining in London. I would recommend you, however, to send a man up with a broom, two or three hours beforehand, to remove the soot from their crosses. The bells at St. Bartholomew the Less are dedicated to St. Augustine, St. Vincent, and St. Michael, the legends being in full—1. "Vox Augustini sonat in aure Dei;" 2. "Vincentius revocat ut canta potia tollat;" 3. "Intonat de celis vox campana Michaelis." The two smaller ones are by a well-known Mediæval manufacturer, William the Founder, and have his arms on them, a A between three ewers. The tenor, about the same date, has the initials S. O., with a cross between them on a shield. It has not yet been identified.

While upon London bells, I may mention that Edward III. erected a clochier, or bell-tower, and placed in it three bells, for the use of St. Stephen's Chapel, at Westminster. On the tenor was inscribed—

> "King Ed. made me thirty thousand weight and 3.
> Take me down and wey me and more you will find me."

This, by the way, if true, is the earliest example known of an inscription in English. They were taken down in the reign of Henry VIII., when some one wrote underneath in chalk—

> "But Henry the Eight
> Will bait me of my weight."

Stow tells the story, explaining that Sir Miles Partridge staked £100, and won them of Henry VIII. at a cast of dice. He, however, affixes it to a clochier standing on the side of the present St. Paul's School, and says that there were four bells, the greatest in England, and called the Jesus Bells.

It is exceedingly difficult to guess the exact date of the oldest bells that have come down to our times. Dates there are none at that early period, rarely even the founder's mark or lettering, which may give the exact cue. In bells of the fourteenth and fifteenth centuries there is not this difficulty; for, though they are rarely dated, they invariably have shields, lettering, and other architectural devices, which enable us to form a tolerably correct guess at their date. These marks, however, are by no means infallible guides to the uninitiated in such matters; for foundries often went on for generations, and marks and stamps were handed down from father to son, often for a century or more. A little close inspection, however, will usually afford some slight addition, either in the stopping or moulding; which decides against the hoped-for antiquity. I have myself several times seen Mediæval shields and lettering upon bells only dating early in the seventeenth century: a date in Arabic numerals often unravels the mystery. Dates came in about 1570 in England, and have been continued ever since. In foreign countries they are met with much earlier. The earliest known dated bell is at Freybourg. Its diameter at the mouth, according to Mr. Tyssen, is 57 inches; height, 5 ft. 5 in.; weight, about 2 tons. The inscription is, "+ O Rex Glorie veni cum pace,—me resonante pia populo succurre Maria,—A.D., 1258." At Duncton, in Sussex, is a bell which Mr. Tyssen supposes to be the earliest dated bell in England. The date on this is 1319. This also is of foreign manufacture. At all Hallows Staining, London, is another, with an inscription in honour of St. Martin, dated 1458.

[The author here quoted a variety of inscriptions from ancient and modern church bells, and proceeded to state]

It is very desirable that some steps should be taken to ensure decent inscriptions on church bells in the present day. With a few notable exceptions, as St. Gabriel, Pimlico; St. Paul, Brighton; Hurstpierpoint, Sussex; where the clergy have taken the matter up, either nothing but founder's name and date, and those of the parochial authorities, or else such rubbish as was allowed to be put up at Sherborne only a few years since, was found.

Bells in the Mediæval period, like most other productions of that age, are well deserving of study as works of art. A vast field of beautiful lettering and diapered ornamentation may be gleaned from the belfries of East Anglia. I have not made very extensive researches in the northern and western districts of England, but from what I have seen they must yield the palm to Norfolk, Suffolk, and Lincolnshire. The same must be said for the southern counties.

I think we may safely point to Lynn, in Norfolk, for the earliest specimens of these beautiful castings, many of which are, in their way, fully equal to what have come down to us in illuminated MSS. We find the names of Thomas and William de Lynn, of Johannes Godyng de Lynn, of the Wambis and Schep families, connected with this art during the fourteenth century, all more or less diffused over East Anglia, and using lettering and stamps and diaper nearly identical. One could heartily wish that more specimens of their work remained, but the custom of augmenting peals for ringing purposes during the eighteenth century in all the larger parishes has made terrible havoc amongst them; the chances of a successful find being now much greater in the inaccessible village bell-cot than in the stately well-newelled tower. The inscriptions on the bells of this period are invariably in single capitals, each capital highly adorned, the initial ones especially so, with diapered ornament. Often the human figure is combined to suit the shape of the letter, usually in ecclesiastical costume. Many of the initial capitals are besides beautifully crowned. The inscription always begins with a floriated cross, more or less elaborate; and between each word is a stop, usually a fleur-de-lys, or sprig of some pattern. The canons are often besides elaborately moulded.

Bells with ornamentation of this particular character are not found in the fifteenth century. Whether the Lynn foundry died out, or whether it was absorbed in or removed to Norwich, I have not yet been able to discover. All we know is, that with the fifteenth century arose a very flourishing foundry in Norwich, conducted for some generations by the Brazier family. They seem to have founded largely, as their bells are still very numerous throughout Norfolk. With them came in a totally different kind of ornamentation. Black letter was now used exclusively, and of a very superior character. The capitals were still remarkably beautiful, and, as before, often crowned. A new class of initial crosses and stops were also produced. The bells from the Norwich foundry may be readily recognised by the presence of a shield upon their crown. This shield is of three sizes, and somewhat different in detail, on each of them a ducal crown between three bells arranged heraldically. The earliest shield had a simply diapered field. This was afterwards replaced by an ermine ground in two sizes. This foundry was carried on by various hands till nearly the middle of the last century. After the Reformation they made an attempt to return to the characters of the Lynn foundry; but whether they had preserved the original stamps, or had copies made from them, I cannot say. I am inclined, however, to the latter opinion.

Contemporaneously with the Norwich foundry was another at Bury, probably connected with the Abbey. They had a good business in Suffolk and Essex, and a little in Norfolk; their castings, however, are rough and inferior to those of the Norwich foundry. Their bells may be easily recognised by a shield, consisting of a bell pierced by two keys in saltier, a chief with a ducal crown between two pairs of arrows compounded from the arms of Bury St. Edmund's, together with a rude representation of some of their tools. This foundry came into great note under Stephen Tonne, towards the end of the sixteenth century, many of the largest and best bells in Essex and Suffolk being of his manufacture. It was afterwards removed to Thetford, in

Norfolk, and either died out in the middle of the last century, or was revived again at Downham under Thomas Osborn.

The above foundries were confined to East Anglia, as was also the Sudbury foundry, of some note in the last century. Much information concerning them, particularly during the early period of their existence, has been gathered by Mr. Lestrange, of Norwich, which he hopes shortly to print. The book will be fully illustrated with specimens of the crosses, stamps, and letterings used in the fourteenth and fifteenth centuries. Other ornaments were also common besides the stamps, crosses, and lettering. I have several times met with the Evangelistic symbols used as stops between the words of the inscription; also the various emblems of saints, sometimes figures of the saints themselves, sometimes a rood with attendant figures of St. Mary and St. John. On the tenor at Minster, in Thanet, the inscription begins with a good demi-figure of a priest in eucharistic vestments. Flowers were also largely used as borders. I have met with a beautiful border of daisies on a bell dedicated to St. Margaret.

Leaving East Anglia we find other foundries of early date in other parts of England; but having but scanty information concerning them, I will not detain you upon them. There are, however, certain founder's marks which were used pretty generally over England, for which a home has not yet been found —possibly they were itinerants. In the sixteenth and seventeenth centuries there was hardly a large town in England without its foundry. Many of them turned out beautiful bells so far as sound is concerned, but as works of art there is little to say concerning them. The most celebrated founder in the seventeenth century was Miles Gray. His head-quarters were at Colchester, but he itinerated considerably; the number of his bells yet remaining is marvellous, and not less remarkable is the exceeding beauty of their tone. There are some twenty or thirty of his tenors yet in Suffolk, and that at Lavenham, though in no way better than several others, has been often moulded by bell-founders. So great was Gray's reputation, that the great bell at St. Nicholas, Newcastle-on-Tyne, called the Mayor's Bell, weighing over two tons, was sent all the way to Colchester to be re-cast by him. Richard Oldfield cast some very fine bells about the same period, or a trifle earlier; his remaining works are but few—only, so far as I am aware of, to be found in Essex and Herts. A kind of lettering was adopted by him in very good imitation of fourteenth century work; his mark was an arrow on a shield between his initials in chief and quatrefoil and fleur-de-lys. The only other founder of this age that I shall mention is Richard Chandler: of his whereabouts I am uncertain, and I have only seen some dozen of his bells, in Bucks, Herts, and Cambridgeshire, but his tenor bell at Melbourne, near Cambridge, is one of the finest bells in existence for its weight.

The last century saw the extinction of most of the smaller foundries, or rather their absorption into the two greater establishments at Gloucester and Whitechapel. The Gloucester foundry had existed for many centuries. John of Gloucester was a bell-founder there in the thirteenth century; but under the Rudhall family it chiefly came into note during the last century, upon the decline of the Salisbury trade. Its turn came at last for amalgamation with Whitechapel, which foundry, at the beginning of the present century, may have been said to have been the foundry for England; Market Downham, in Norfolk, the last of the East Anglian foundries, being also sucked into it. There was again a considerable establishment in Reading during the sixteenth and seventeenth centuries: this was removed by the Knights to Southwark, in 1750 or thereabouts; and that again flowed into Whitechapel. At the present time we have three foundries in England: the old-established house of Mears; the Messrs. Warner, of Cripplegate, who are now getting into a large business in this department; and the Taylors, of Loughton, of whose bells I can also speak very highly, having had several orders executed by them.

So much in a very cursory way for the history of bells and bell-founding in England. I will now push on to the practical part of the subject, with which we are more particularly concerned. With all thanks to our three worthy founders of the present day for what they have done and are doing for us, I will still say, and I know that if any of them read this they will feel that I am only speaking the truth when I say, that the art of bell-founding in the present day is not what it ought to be, or what it might be. I lay very little blame, however, on their shoulders; for I am sorry to say no art has met with so little encouragement as the art of bell-founding, or has been more crippled by the fatal mistake of expecting great results from very little money. And, believe me, nothing is more easily starved than a church bell. People now expect to get a peal of six for no more than the cost of a proper tenor. Everything in a bell is the quality of the tone; the note is a mere result of certain dimensions, and may, I believe, be reached by metal little thicker than paper. Tone depends on the material, the shape, and the thickness of the metal. Consequently, bell-founders are sorely tempted to do the best they can for very inadequate sums of money, and with a result that pleases no one. And so, many a tower is only furnished with the odious ting-tang, that might have had a peal had there been reasonable hope of securing the grand and mellow tones of former days.

Again, as to the lettering, stopping, and ornamentation of bells, —Why are these now altogether abandoned? It is true our founders have a black lettering, which can be used if asked for; but something better than any of them have yet is easily attainable; and, when once the moulds are made, a good design costs no more than a bad one. It may be said bells are out of sight, and so what is put on them does not very much matter, I think it does. A bell is a sacred instrument, dedicated to the service of God, and religious art may be brought to bear upon it just as rightly as upon other sacred vessels. The fact of its being seen but by few does not appear to me to affect the question; for we have got beyond the notion prevalent some fifty years since, that that only need be decent which meets the eye of man. The same rule applies to the careful selection of dedicatory inscriptions. Now in the nature of the case it cannot be expected that each architect should provide the bell-founder with designs for the bells of any given church; but I think it should be the care of this Institute to provide each founder with legitimate forms of lettering and stops.

The next suggestion I would offer is this. We either find nothing but our little enemy the ting-tang, or an ambitious scheme for a peal of six or eight, too often realised only in skeleton by the tenor, its third, and fifth, forming what may be called a hop-skip-and-a-jump style of music, the constant repetition of which is far from pleasing to the ear; and but too often the further development of the peal is unrealised. The Marylebone churches, early in the present century, were furnished with these skeletons of peals of six, and they have hopped, skipped, and jumped for the last forty years, without the least sign of filling up their gaps. I am sorry to find they have even had the contrary effect of inducing other steeples to follow in their frolics: for St. Paul's, Knightsbridge; All Saints', Margaret-street; and some others, have begun a similar skirmish. Now instead of this unsatisfactory music, why not be content with a really good tenor and one bell next above it? Nothing can be grander than two good bells chiming thus together. Such music is far preferable to three or four light bells at odd intervals. I am, of course, only alluding to those churches where peal-ringing is not contemplated. You are all of you probably familiar with the grand and pleasing effect of the two heaviest of the Abbey bells at Westminster chiming thus together for daily prayer. It is a return to ancient usage, besides being most dignified in itself, and satisfactory to the ear. Then, by degrees, perhaps, a third bell, also in succession, may be obtained. Three such bells would leave nothing to be desired.

The third suggestion I have to make refers only to peals of five bells and upwards. It is that there is no necessity whatever for the universal adoption of the modern major scale, which, for the last half-century or more, has been the undeviating practice. By so doing, the harmonic combinations are very much limited, and many very pleasing scales in the minor mode altogether ignored. Now minor intervals were great favourites in the sixteenth and seventeenth centuries, from their peculiar plaintivee ness and expression. This fact was forced upon my notice somfew years since, when in charge of a Suffolk parish. The church tower nearly adjoined the rectory; and the peal of five was a very light one, the tenor only 8 cwt. I was for some weeks puzzled to account for its pleasing effect. Suddenly the fact dawned upon me that it was in the key of A minor. I at once took the hint, and tested the keys of all the peals in the neighbourhood: the result was the discovery of several other examples. I have tried a great many peals of the present century, but I have not yet discovered one in the minor mode. I speak under correction when I say that I do not believe there is one in all England. Now, accepting the major and minor modes as equally legitimate, see what an increase of harmonies we have. Taking D natural as the correct tenor note, and A natural as the highest for any peal, we get eight different keys for our peals; and by flattening the third, to bring them into the minor mode, the number is doubled.

After all, however, we must remember that, so far as bells are concerned, an exact sale, in present received musical expression, is of no moment whatever. So long as a peal of bells is in harmony with itself, and satisfies the ear, it matters not in what key it is, or whether in no describable key whatever. It is a great mistake to tie a founder down to any exact key or scale: it is sure to involve that evil instrument, the tuning-lathe, to reduce them to the appointed standard of pitch; when most probably they were much better when first broken out of the moulds, and even more pleasing to the ear. No bell is ever cast thicker in the sound-bow than it ought to be. The thickness of the sound-bow should be one-thirteenth of the diameter; that of the waist, one thirty-sixth of the diameter of the mouth. Many are cast far below this standard, for economy's sake. When, therefore, the tuning-lathe is brought to bear upon a bell, we may be certain that the tone is being sacrificed to the note; and if this is bad in modern bells, what shall we say to paring down fine old bells, as I have seen done, to fit them to the shallow tones of modern additions to the peal? It is, I fully believe, to facilitate this tuning process that the proportion of copper to tin in present use is so much greater than it ought to be. The modern practice is to make the proportions three parts copper to one of tin. Now, as tin wastes considerably in the fusing, this is far too small. The proportions ought to be in thirds,—two of copper to one of tin. Bell-founders say that such a proportion is liable to render the metal somewhat brittle; and this, coupled with the thinness of the bells in the present generation, greatly increases the risk of a fracture. There is a remedy for this, however: there is no reason why the metal should not be reduced to a state of fusion twice before being allowed to run into the mould. Then, again, in the present day the melting process is a rapid one in a roaring furnace. In former times it was slower, mostly with timber fires, and dross had opportunity of escape, which now is all fused into the bell.

I need hardly tell you that the prevalent idea of silver entering largely into the composition of ancient bells is a pure myth. So far as sound goes, silver is little better than lead, and would spoil any bell where largely used. The idea has, no doubt, arisen from the much larger quantity of tin formerly used. Mr. Lukis relates, in his little work on Wiltshire bells, that when the peal of Great Bedwyn Church was taken down to be re-stocked, the canons were found to have become white in places where there had been friction, and nothing would persuade the workpeople that it was tin, not silver, that they saw. The old bell of St. Laurence Chapel, Warminster, in which tin had been largely used, was also traditionally said to be rich in silver. When it was re-cast, in a field adjoining the chapel, in 1657, a good deal of additional silver was thrown in by the inhabitants, as they thought to improve its tone still further. An old foreign bell at St. John's College, Cambridge, from its sweet tone, is popularly called the Silver Bell; this, of course, being a similar delusion. The same may he said of another very pretty bell at Acton, Middlesex, called the Acton Nightingale.

Another great difference between bells, ancient and modern, is in their shape. The most ancient bells were very long in the waist, and high in the shoulder, many of them to an exaggerated degree; we now run into the opposite extreme of short waists and flat shoulders. The reason of this change is obviously connected with the art of ringing, short bells being much easier to raise, and taking up less room than bells of the old proportions. The modern founders are all in favour of this change, asserting that the note is identical in both cases; and that metal lying in the waist is useless. If they would be content with saying that it is a more convenient form, both for the pockets of the customers, the ringers, and their own moulds, I should agree with them; but there is no denying that, though the note may be identical, the quality of tone is very different, and this is evident on acoustic principles. The waist of a bell is, so to speak, its soundboard. The scientific view of a bell is that of an elastic instrument composed of an infinite number of rings or circles, varying in tone according to their several dimensions, the sound arising from the vibratory motion of all of them when set in motion by the clapper. A bell properly and truly cast will give the notes of a common chord more or less blended into one, and major or minor according to its height. The fact is easily ascertained by striking the bell with the hand, or with a stick, in three different places: the note of the bell will form the base where the clapper strikes, and its third and fifth will be given at certain distances above. This flat bell-founding is, I fear, on the increase, and the lips are now so extended that a section of the bell would almost describe an ogee arch; hence we get the same notes at about half the weight of metal employed by our ancestors. I believe this system was first brought out at Downham,, late in the last century. It was certainly adopted, with Dobson, into the Whitechapel foundry, for their earlier bells were of a more pleasing shape. Where money, however, is not a very pressing consideration, we still see the use of earlier and more graceful forms.

As regards weights of tenors, I think some fixed rule should be adopted; for instance, a tenor to a peal, say of ten or twelve in D, should range from 40 cwt. to 50 cwt.; and for a peal of eight, not less than 35 cwt. A tenor in E ought not to carry a peal of more than eight, and should range from 20 cwt. to 35 cwt.; but no one should attempt in E under 20 cwt.; now we sometimes see one as low as 15 cwt. F is the usual tenor for peals of six, and should range from 16 cwt. to 25 cwt.; and G, also available for six, but better for five, should never be under 13 cwt. No higher note should be allowed for the tenor of any peal; nor should any treble be of a higher note than F natural, all the higher ones being harsh and unpleasing. And as we must not go higher than F, neither need we go lower than D. The tone of very heavy bells in the notes of A, B, and C, may be very grand as a sort of bourdon, but they are destitute of a musical effect, besides being impossible to raise for the purpose of ringing. No note is so pleasing to the ear, or so desirable for a tenor as E; even D is inferior to it, though the cost is greatly augmented.

With all care, however, and attention to these suggestions, and others also, known only to the bell-founder, another great agency is necessary to perfect a bell. It is a fact, of which there is no gainsaying, that no bell, be it made ever so carefully and skilfully, sounds so well at first as it does after it has been hung some years. There is an atmospheric effect, a process of oxidization, very gradual, which goes on improving and mellowing the quality of tone as years advance. I have noticed this in several instances, and believe it to be an unvarying process. The colour of a bell changes in a few months: a greenish tint and crust come upon it; and after a long course of years the surface becomes slightly uneven, just as we are accustomed to note the process of de-vitrification in ancient painted glass. I believe it is to this process that the peculiarly quaint tone of the most ancient bells may be attributed.

Having thus pointed out the limits of a peal, I must add a word or two on the origin of change-ringing. As before stated, it was introduced early in the seventeenth century, and led to a complete revolution in the art of the bell-founder as well as of the hanger. From that time all the heavy chimes of three and four and five were reduced in weight, and multiplied in number, forming peals of six, eight, ten, and twelve, Whole wheels were necessitated in place of the old three-quarter arrangements, and often the still simpler one of leverage only. King's College, Cambridge, has the honour of having possessed the first ringing peal of five in the kingdom. According to one tradition they were a present from Pope Calixtus III. to the college; and, according to another, they were taken by Henry V. from some church in France after the battle of Agincourt, and by him presented to the college: possibly the archives of the college may be able to clear up the matter; at any rate, they were only chimed like other bells in that generation, though it is highly probable that they were the first peal on which the art of change-ringing was tried. They were heavy bells, the tenor being as much as 57 cwt.; whereas the tenor of the present famous peal of the University Church in that town is only 30 cwt., or half the weight. These bells were hung in a wooden tower westward of the present chapel, and are alluded to by Mr. Major, the historian, who, writing about 1518, states that whilst he was of Christ's College he frequently lay in bed to hear the melody of these bells, which were rung early in the morning on festivals, and, being near the river, was heightened by the reverberation of the water. On the taking down of the bell-tower the bells were suffered for many years to remain unused in the ante-chapel, but were sold about the year 1750, to Phelps, the founder, of Whitechapel, who melted them down. I suspect their sale had something to do with the erection of some new college buildings.

Peals of eight were hung in a few churches early in the seventeenth century. In 1667 came out the first book on ringing; and soon after the number of peals was increased to ten, and then to twelve. The first peal of twelve was hung in York Minster in 1681, tenor 53 cwt.; Cirencester, in Gloucestershire, followed next; then St. Bride's, London, in 1718; St. Martin's-in-the-Fields, 1726; St. Michael's, Cornhill, 1728; St. Saviour's, Southwark, 1735.

The honour of the invention of change-ringing is said to belong to a Mr. Benjamin Anable, who died at an advanced age in 1755. His methods were much improved and enlarged by Mr. Holt. These, together with a Mr. Patrick, have produced some of the most celebrated peals.

In conclusion, this lecture has been for the most part but in outline; time has not allowed me to fill in many a detail which I could have wished. My object, however, has been rather to suggest than to satisfy,—to give you the starting-points from which to prosecute your own researches, as opportunity or inclination may offer; I trust, therefore, it may not fail of some practical effect. Taken as works of art, our bells need a re-infusion of ancient taste; there is no reason why they should not be made as comely in shape and ornamentation as they were in the fourteenth and fifteenth centuries. There is no want of appreciation amongst our bell-founders of the beautiful lettering, stops, and crosses on many a bell which comes to them, alas! only to be melted down. I have been favoured with the loan of a very beautiful volume, belonging to Messrs. Mears, containing fac-similes of many of the best ancient bells that have been sent to them for recasting; and with only some encouragement from the patrons of art, we should see our bells once again such as we might be proud to own; and not only in the matter of decoration, but still more in shape, in composition, and consequently in quality of tone, should we push on for improvement. With the scientific knowledge and applications of the present century we ought even to surpass the bell-founding of previous centuries, though we may learn of them to advantage in many things. We have seen great progress in the minor details of art, both sacred and secular, within the last few years; it has arisen in great measure from carefully tracing its sources and investigating first principles. There is much yet to be learned on the subject of bells, much to be done before we can hope to arrive at the perfection which was attained even three centuries ago, when the following inscription could be honestly written:—

"Me melior vere
Non est campana sub ere."

ON MARINE ENGINES FROM 1851 TO THE PRESENT TIME.

(Concluded from page 108.)

Having referred to the improvements in the arrangement of condensers, &c., for direct-acting engines, attention will now be given to those adopted for double piston-rod engines. It must be borne in mind that for this class of engine the prolongation of the piston rods beyond the crank-shaft greatly deteriorates the arrangement of the air-pumps and condensers, in relation to the space occupied by those for single piston-rod engines. In the examples now given, the air-pumps are worked by the steam piston, and as near the base line as possible. The condensers are separately arranged outside the guides of the piston rods of each engine; the suction-valves are inverted above the top of the air-pump, as in the last examples; the discharge chamber is between the air-pumps and the valves, on the same level as those for the suction. It will thus be understood that both suction and delivery are at the side, over, and extending the length of each air-pump, instead of being directly over them, as in some cases.

The next example worthy of notice is arranged as follows:—The condensers and their appendages are beyond or outside the guides of each engine, the air-pumps deriving their motion as in the previous examples, and are as near the base line as possible, so situated as to clear the guides. Partially over and beyond the side of each air pump are the discharge valves, above which is the discharge chamber; over this, and at the side of the same, is the condenser with the suction valves inverted.

I will now allude to the system of condensation known as surface condensation. Mr. Hall, in days of yore, introduced the tubular arrangement with great advantage. Engineers at that time were slow in appreciating the then presumed gain, and it is only lately that we have seen the surface condenser universally adopted by the powers that be. To condense steam properly is undoubtedly to reduce it to its natural or original state. Now, in the ordinary condenser we bring water into actual contact with the steam to condense it. Surface condensers are to be recommended, particularly for one reason—viz., the production of distilled water for the feed of the boilers. The arrangement of the tubes in surface condensers entails practical difficulties as to the position most suitable, whether they be inserted transversely, perpendicularly, or longitudinally, to the hull of the ship; renewal of the tubes being often required (sometimes while at sea) from corrosion.

The means adopted to render the connection of the tubes in the plate air-tight are numerous. The usual mode now is india-rubber rings recessed in the plates encircling each tube—compression being obtained by a nut for perpendicular tubes, and by the vacuum in the condenser for those of horizontal positions; this is simple and efficacious, and at the same time economical. It must here be remarked, however, that compression of the india-rubber by vacuum can only be attained when the steam is condensed by the external surface of the tubes or within the plates. The circulation of the water is either through or surrounding the tubes, and is produced by pumps with plunger-piston or centrifugal action. The position of the piston-pumps is horizontal, motion being derived either from the steam-piston or piston-rod. The centrifugal-pump requires a separate engine, or spur-gearing, &c., from the crank shaft to give the required velocity.

The values of the two arrangements now used for the condensation of the steam are about equal. In the case of the water surrounding the tubes, the steam passes through the same, and in the case of the steam surrounding the tubes, the position of the water is reversed.

It is obvious that where internal condensation is effected a greater number of tubes are required, in relation to those of the external system—the inner surface of the tube being less than that of the outer. The advantage gained by the steam entering the tubes may be said to be—access for cleaning without disarrangement. Injection or ordinary condensers are more generally used than those of the surface kind, on account of the economy in the outlay of capital at the commencement.

The injection valves for ordinary condensers are generally of the solid or gridiron type, the latter to reduce the stroke to open and close. The pipe for the dispersion of the water is usually a tube, with apertures of an elongated or circular form. An improvement has lately been made in these pipes, by contracting the area for one-half the length, thus equalizing the diffusion of the water throughout.

The next valve necessary for the condenser is the shifting valve, which is a single disc of gun metal, with a slight spiral spring at its back or upper part. A screwed spindle is universally used to prevent the valve from rising, after the water and air in the condenser have been blown out previously to starting the engines. It might be deemed neglectful if I were not to make allusion to the bilge injection-valve or cock, whichever may be used. This valve, as is well-known, is only required in cases of necessity, such as leakages, or disarrangement of the bilge or donkey pumps. I would beg to suggest that the bilge water should not be allowed to enter the condenser, on account of the generally impure state of bilges. A valve and box might be arranged at the end of the air-pump for this purpose.

The portions of the marine engine next for exemplification are the feed and bilge pumps. The position of these is so arranged that a free access can be obtained to the valves and surrounding parts without disarrangement. Some makers prefer to work the feed and bilge pumps in a line with each other, with one rod and plunger direct from the steam-piston. Other firms secure the pumps side by side to the discharge water-pipe of the condenser, each plunger being connected to the piston-rods crosshead; this latter improvement is more general than the former. In the case of hollow plunger or trunk air-pumps, those for the feed and bilge are on each side of the air-pump, and secured by nuts or keys. Before terminating this portion of the subject, it will be well to add that the valves for the air, feed, and bilge pumps are now universally discs of india-rubber, instead of the gun-metal spindle-valves.

It will have been observed that no allusion has yet been made to the arrangement of combined high and low pressure engines. For the purpose of comparison, I will alude only to those arrangements in common use. The position of the low pressure cylinders is side by side, as for those of the ordinary kind; in some

Twin Screw Propulsion.—Tabular Statement of Ships, Marine Engines, &c., constructed by Messrs. Dudgeon, Blackwall, since 1851 *to the present date, supplied by the Firm.*

Beam of Vessel.	Length.	Depth.	Tonnage.	Immersion.	Nominal horse power.	Diameter of cylinder.	Length of stroke.	Kind of Condenser.	Diameter of air-pump.	Diameter of screw propeller.	Pitch of screw propeller.	Distance between centres of propellers.
ft. in.	ft. in.	ft. in.	tons.	ft. in.		inches.	inches.		inches.	ft. in.	ft. in.	ft. in.
22 6	150 0	13 0	395	9 0	120	26	21	Injection.	8½	7 0	14 6	8 9
23 0	165 0	13 6	425	—	—	—	—	—	—	7 5	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
34 0	225 0	22 0	1258	17 0	150	H. 24 L. 50	24	—	12	8 10	16 0	11 8
25 0	175 0	15 0	531	9 6	200	34	21	—	11	8 3	16 0	10 5
23 0	165 6	13 0	425	9 0	120	26	21	—	8½	7 0	14 6	8 9
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
11 10	57 6	7 0	35	4 10	30	12	11	High Pressure.	None.	3 8	7 4	4 6
23 6	200 0	13 4	546	9 6	200	34	21	Injection.	11	8 0	16 0	9 5
15 0	85 0	6 6	91	2 9	30	12	11	High Pressure.	None.	3 6	7 4	4 6
—	—	—	—	—	—	—	—	—	—	—	—	—
34 0	265 0	28 0	1500	16 0	350	H. 31 L. 62	24	Surface.	11	10 6	18 0	12 0
17 0	100 0	6 6	138	3 6	30	12	11	Injection.	5¾	4 0	7 6	5 4
32 0	160 0	13 3	737	10 0	200	34	21	—	11	8 0	16 0	9 5
24 6	200 0	13 4	592	9 6	—	—	—	—	—	—	—	—
28 0	250 0	15 6	972	10 0	300	40	22½	—	13	9 2	17 3	10 9
—	—	—	—	—	—	—	—	—	—	—	—	—
27 0	230 0	14 6	829	9 6	250	37	21	—	12	8 9	16 0	10 0
21 6	120 0	13 0	436	10 0	120	26	21	—	8½	7 0	14 6	8 9

Tabular Statement of Marine Engines Constructed by Messrs. John Penn and Son, Greenwich, supplied by the Firm.

SCREW ENGINES.

	Minotaur.	Achilles.	Warrior.	Black Prince.	Resistance.
Diameter of cylinder	104¼	104¼	104¼	104¼	70¾
Length of stroke	4 ft. 4 in.	4 ft. 0 in.	4 ft. 0 in.	4 ft. 0 in.	3 ft. 6 in.
Revolutions per minute	...	52½	54¼	51¾	68 to 69
Diameter of screw	24 ft. 0 in.	24 ft. 0 in.	24 ft. 6 in.	24 ft. 6 in.	18 ft.
Pitch of ditto	25 ft. 6 in.	25 ft. 6 in.	30 ft. 0 in.	30 ft. 0 in.	21 ft.
Nominal H.P	1350	1250	1250	1250	600
Indicated H.P.	...	5746	5471	5146	2424
Speed of ship	...	14·25 knots	14·35 knots	13·31 knots.	11·84 knots
Date of trial	...	Dec. 28, 1864.	Oct. 17, 1861	Aug. 30, 1862	Sept. 23, 1862

PADDLE-WHEEL ENGINES.

	Exploratore.	Taliah.	Izzeddin.	Victoria.	Prince Imperial.
Diameter of cylinder	72 in.	72 in.	66 in.	58 in.	52½ in.
Length of stroke	5 ft. 0 in.	5 ft. 0 in.	5 ft. 0 in.	4 ft. 6 in.	4 ft. 0 in.
Revolutions per minute	40	39	41½	42	48 to 49
Diameter of axis of wheel	19 ft. 0 in.	19 ft. 0 in.	17 ft. 6 in.	17 ft. 6 in.	14 ft. 11 in.
Length of floats	10 ft. 0 in.	10 ft. 0 in.	10 ft. 0 in.	7 ft. 10 in.	8 ft. 0 in.
Depth of ditto	4 ft. 6 in.	4 ft. 6 in.	3 ft. 10 in.	3 ft. 6 in.	3 ft. 2 in.
Nominal H.P.	350	350	300	220	180
Indicated H.P.	2556	2540	2373	1640	1480
Speed of ship	17·27 knots	17·74 knots	16·5 knots	16·83 knots	16·3 knots
Date of trial	May 6, 1863	Dec. 28, 1863	Sept. 19, 1864	Sept. 3, 1861	Sept. 28, 1864

The folowing is a list of engines constructed by Messrs. Maudslay, Sons, and Field for H.M. Navy since 1851 to the present date, kindly furnished by Joshua Field, Esq.:

	Horse-power nominal.
Engines, &c., for 75 Screw Vessels	Total 37,570
„ „ 26 Paddle „	„ 6,340
„ „ 69 Screw Gunboats	„ 4,260
Total	48,170

Table showing particulars of some of the Principal Marine Engines, recently constructed by Messrs. R. Napier and Sons, Glasgow.

Names of Vessels.	Paddle or Screw.	Material.	Tonnage O. B. M.	Kind of Engine.	Number of Cylinders.	Diameter of cylinder.	Length of stroke.	Nominal horse power.	Kind of Boilers.	Kind of Propeller.
						inches.	ft. in.			
Coromandel	Screw	Iron	—	Plunger, direct	2	50	2 6	250	Tubular.	Common.
Gunboat for H. E. I. Co.	—	—	—	Horizontal, high pressure.	2	18	1 6	80	Tubular.	—
Emperor Alexander ...	—	—	—	Plunger. direct.	2	60	3 0	350	—	—
Islesman	—	—	197$\frac{61}{94}$	Horizontal.	2	24$\frac{1}{8}$	3 0	80	Tubular.	—
Victoria	Paddle	Iron	144$\frac{78}{94}$	Oscillating.	2	27$\frac{1}{16}$	3 0	44	—	Radial.
Fifeshire	—	—	—	Inclined.	2	36$\frac{1}{8}$	3 6	82	Lamb's flue.	Eccentric.
Chevy Chase	—	—	963$\frac{8}{94}$	—	2	72$\frac{1}{8}$	8 0	416	Tubular.	—
Royal William	Screw	Wood	—	Plunger, direct.	2	65$\frac{1}{8}$	3 0	500	—	Griffiths.
Cormorant	—	—	—	Plunger, direct.	2	45$\frac{1}{8}$	2 0	200	—	Griffiths.
Scotia	Paddle	Iron	4050$\frac{88}{94}$	Side lever.	2	100	12 0	1000	—	Radial.
Orestes	Screw	Wood	—	Plunger, direct.	2	60$\frac{1}{2}$	3 0	400	—	Griffiths.
Clan Alpine	Paddle	Iron	1507$\frac{80}{94}$	Inclined.	2	64	8 0	400	—	Eccentric.
Wolf	—	—	870	—	2	61	6 0	275	—	—
Rolf Krake	Screw	—	1091$\frac{12}{94}$	Horizontal direct.	2	48	2 0	235	—	Griffiths.
Osman Ghazy	Screw	—	4221$\frac{61}{94}$	—	2	92	4 0	900	—	—
Abdul Aziz	—	—	4221$\frac{31}{94}$	—	2	92	4 0	900	—	—
Orkman	—	—	4221$\frac{61}{94}$	—	2	92	4 0	900	—	—

Total number constructed by this firm, from 1851 to 1864 inclusive—Screw engines, 87; Paddle engines, 39.

cases annular cylinders are used, viz., the high pressure cylinder within that for the low pressure. Another arrangement is the high-pressure cylinder on the top of that for the low pressure. A third arrangement has the smaller cylinder at the back end of the larger. A fourth example consists of two high-pressure cylinders in front of one for low pressure, the former acting as guides for the piston-rod. The means adopted for imparting the motion of the piston to the cranks are of the ordinary arrangements already described, with the exception of the necessary extra piston-rods and stuffing-boxes.

Having alluded to the different engines, and their details past and present, adapted for the single screw, I will now call attention to a notice of arrangement of engines as at present used for the twin or double screw system. It must here be mentioned that the class of engines now under notice have precisely the same duty to perform as those before described, consequently, if I pass over the major portion of the detail it is to avoid repetition.

The arrangement of the engines is usually separate for each screw. The type of engine generally adopted at present is direct-acting, with surface or injection condensers. Single piston-rod engines seem to be more in favour than those of the double piston-rod return action type, I presume on account of the simplicity of the former. The position of the arrangement in plan is side by side—port and starboard—instead of directly opposite each other; this is owing to the space required for the arrangement adopted, and the small beam of the vessel; but in some cases engines are arranged opposite each other, with a great reduction of space compared to that of the side system. When the crank shaftings are connected the steering principal is destroyed, and the twin screw system, so far as regards propulsion, is very little better than the single system.

There is not the least doubt that as a mode of steerage the twin system is correct, and for shallow draughts it is advantageous. To suppose the plan to be universally correct for large vessels requires, however, more practical evidences than I at present possess; but of this I am confident, that for small or large vessels, whether for commercial or war purposes, the twin screws, when driven separately, are invaluable for steering. The advantages for war ships are principally the facility for manœuvring when under an engagement. Let it be presumed that the enemy has aimed at a twin-screw steamer: by a contrary action of the screws her position can be shifted instantaneously, and the intended evil postponed, if not averted.

I have come to the end of my brief description of the marine engine, and will now allude to the weight of material, cost of marine engines, and the relation of nominal to actual horsepower, together with the consumption of fuel. The variation in the weight of marine engines is due to the design and arrangement as much as the material used. Double trunks may be said to be a fair example as to the average weight of marine screw engines. Return connecting-rod engines are perhaps the heavier, in comparison to those of the single type, in relation to rods and guides. High and low pressure engines combined are the heaviest of any examples yet given. The materials comprising the different portions of the engines of the present day are of six kinds —first, cast-iron, of which is formed the cylinders, pistons, valves, casings, main frames, guides, condensers, &c.; secondly, wrought-iron, comprising cranks and shafts, piston and valve rods, links, levers, weigh-shafts, bolts, nuts, &c.; thirdly, steel, for springs, small pins, &c.; fourthly, gun metal for bearings, guide blocks, bushes, glands, nuts, &c.; fifthly, copper, for pipes of all kinds required for steam and water; sixthly, india-rubber, for valves, packing, &c. For the present occasion, in reference to weight, I have selected twelve examples of marine screw engines, each varying in power and design. The examples of arrangement being in pairs, the result has been that 4·334 cwt. per nominal horsepower may be taken as the average weight of material, exclusive of boilers, fittings, screw-propeller, and alley-shafting. It may here be observed that each maker of marine engines in the present day differs in design and arrangement, consequently, the weight of trunk engines by different makers would be unequal. The same may be said for single piston-rod engines, as well as for double piston-rod return connecting-rod engines.

I now come to that portion of this subject which is the crowning question of all, and too often the cause of much controversy in political and commercial circles—viz., what is the cost! My opinion is, that it is perhaps the most difficult query to answer that could be put, and the only reason for its introduction is to preserve myself from presumed neglect in not noticing this important matter. To ascertain correctly which is the cheapest class of engine now in use, is a problem much too difficult for me to solve; but I will, however, tender such information as I deem reliable.

The price of a marine engine depends entirely on the class of workmanship. Should a roughly-finished engine and boiler be required, with more painted than polished surfaces, the cost will be reduced in comparison to that of the more highly finished. The fittings also greatly regulate the outlay. Some companies pride themselves on this portion of display, others, again, look on it as an unnecessary expense; so, to draw a correct line of comparison would involve the amalgamation of the many ideas in order to give a fair evidence. I feel confident, however, that marine engines, with boilers and fittings complete, can be produced of certain classes for £70 per horsepower nominal, and the same can be reduced to £50 per horsepower; each price of course being under certain conditions as to terms and workmanship.

Allusion must now be made to the power, &c. of marine engines. Nominal power is a term used, particularly for commercial purposes. Each maker has his private rule, hence the difference in dimensions in engines of the same class and power. Actual horsepower is defined by the indicator diagram, speed of piston,

&c.; the ratio between the nominal and actual power is in some cases low, in others high. The writer has known instances where, the nominal power being 1·0, the actual was 6·0; and in others, nominal 1·0, actual 2·123; the average ratio at present is, nominal 1·0, actual 4·0 to 5·0. With reference to the consumption of fuel, there is a great difference in the evidence. Superheating and surface condensation are slowly making progress, and at the same time reducing the consumption of fuel in ratio to the amount of water evaporated or steam used. The average actual horsepower expended per cubic foot of water evaporated is, water being 1·0, actual horsepower 2·635 to 4·0, and doubtless in some cases more. The ratio of fuel consumed in pounds per hour to the actual horsepower per hour expended may be taken as follows:—Engines of ordinary construction, power, 1·0; fuel, 5 to 6. For expansive working-engines, with superheating and surface condensation, thus:—power, 1·0; fuel, 2·50.

I am deeply indebted to several eminent firms for their courtesy and practical information received and personally given. Messrs. John Penn and Son, of Greenwich, have kindly given me a tabular statement of much value to the profession and the society. The list now presented commences from the date of November 1861, also that with their class of engines the consumption of fuel is about 4 lb. per actual horsepower per hour for those of ordinary construction, and about 2·5 lb. per actual horsepower per hour for expansive engines, with superheated steam and surface condensation. This firm has displayed a warm interest in the present paper, by kindly lending the photographs and splendid working models, which I have the pleasure of laying before you.

Messrs. Maudslay, Sons, and Field have kindly lent photographs of their late improvements in marine engines. From personal interviews, I am enabled to present the society with valuable information, particularly as follows:—The amount of fuel consumed, per horsepower actual, for ordinary engines by this firm is 5 lb., in some cases less, in others more. For three cylinder expansive engines, with surface condensation and superheating, the consumption is reduced to 2·25 to 2·5 lb. per horsepower actual. These engines cut off at one-seventh of the stroke, producing an almost correct indicator diagram. In one example shown me the nominal horsepower was 150; with a pressure of steam 25 per square inch, the indicator diagram produced a result of 875 actual horsepower, being in a ratio of 1 to 5·833, which may be said to be an exceptional result for screw engines. This firm has constructed since 1851 to the present time, the following number of engines and boilers:—of screw engines, 183; of paddle-wheels, 30. The highest nominal power of one pair of engines yet constructed by this firm is 1350, and the lowest 10.

The Messrs. Rennie have kindly lent me models and photographs of the different classes of engines they are in the habit of constructing. I am informed by this firm that the consumption of fuel for ordinary engines is—actual horsepower 1, fuel 5. In the case of surface-heating, surface-condensation, and expansion—actual horsepower, 1, fuel consumed 2·5; showing a reduction of 50 per cent. on that of the ordinary kind, which is about equal to the other firms.

Valuable statistics have been supplied to me by Messrs. Napier and Son, of Glasgow, giving particulars of the ships, engines, &c., constructed by them from 1851 to the present time. From these I have made a selection for publication. This firm has also kindly presented me with splendid photographs of their engines, &c., which are hung for inspection.

With reference to twin-screw propulsion, I am deeply indebted to the Messrs. Dudgeon, of Blackwall, they having kindly furnished for this occasion practical statistics of the proportions of vessels and engines constructed by them since the year 1851 to the present time.

In conclusion, I must apologise for the length of my present paper; but I beg to observe, that had I extended my remarks to twice or thrice the present length, I should even then have failed in doing justice to this subject, which is undoubtedly one of national importance. To the credit of those concerned it can be truthfully said, that, in comparison with other nations, the productions of our marine engineers maintain that high standard for excellency of design and workmanship which has ever characterised the natives of Old England.

POMPEII.*

By R. Phené Spiers.

I now come to the more interesting portion of my subject, the arrangement of plan, the architecture, and decoration of the private houses. I say more interesting, because, whilst in Greece, Italy, and elsewhere, we have abundant remains, in all states of preservation, of the public monuments and temples built by the ancients, in Pompeii and Herculaneum alone are we able to trace out their domestic dwellings; and, although various descriptions of them have been handed down to us by the Classic authors, still there were many points which remained mysteries till the discoveries of these two cities cleared them up.

The mode of life of the ancient Romans was not very different from that of the present inhabitants of the south of Italy. They rose early, and the greater part of the day was spent in the open air. A slight repast of bread and fruit was taken on getting up: the business of the day was then transacted till noon, when they had lunch, or what we should call "*déjeûner à la fourchette*" (only they had no forks). After lunch came a stroll down to the Forum, where all the public meetings were held, the news heard, and the courts attended to hear the trials. Then those religiously disposed might pay their devotions, either to Jupiter, Isis, Venus, or any other deity to whose worship they specially dedicated themselves. If spectacles were being held, they might go to the ampitheatre or the theatres; and, finally, taking a bath (the most important operation of the day), home to dinner or supper, after which no further business was transacted.

The Pompeian houses seem all to have been arranged on a similar plan, the size and number of the apartments varying according to the rank and means of the owner, and to local circumstances. They consisted generally of two floors only, ground and first floor. The latter, occupied by slaves and servants, was low, of little importance, and extended over a portion of the house only. There is but little architecture in the exterior of the houses, as it was invariably occupied by shops, the light being admitted to the rooms from courts in the interior. This may probably have been for the sake of privacy and protection, glass windows being a great rarity in Pompeii, and also because a shady, sheltered spot, open to the air, in a hot climate, is the greatest luxury one can have. The shops were small. Some had rooms at the back; some had staircases evidently leading to an upper floor, and others communicated with the mansion or house behind. In the latter case the shop was kept by a slave (termed "dispensator") belonging to the owner of the mansion, who thus disposed of the surplus products of his farms and lands. The shops all opened to the street, as they do at the present day in the south of Italy and Sicily, and they were closed at night partly by means of wooden shutters sliding in grooves cut in the stone, and partly by a door swinging on a pivot, the whole fastened together probably by a bar of iron or wood. The grooves in which these shutters were placed are still visible in all the shop-fronts, as also the pivots in their sockets on which the door turned. In many of the shops, particularly those destined for the sale of liquids, counters of masonry, with jars fixed in them, still remain. They have their faces toward the street decorated with small slabs of marble of irregular shape, set in cement and polished.

The names of the different owners were written over the shops in red paint, and some of them had signs of their occupations in bas-reliefs of terra-cotta, many of which are found now. Thus a goat indicated a milk-shop or dairy; two men carrying an amphora, a wine-shop; the phallus, a seller of amulets and love-charms; a man whipping a boy hoisted on another's back, a schoolmaster; and so on. It is difficult, of course, to find out what was sold in the greater number of the shops, their contents having perished or else been removed to the Museum at Naples. The bakers' shops are easily distinguished by their mills and ovens: these latter are similar to our own.

The mills are very curious, and consist of two stones: the lower a cone, with rounded top, somewhat of the form of an egg, with a base or pedestal, and a groove cut in it to catch the flour in its descent; the upper stone, in shape like a dice-box, fits over the lower: in order to lessen the friction, a pivot is let into the upper part of the lower stone and a corresponding socket fixed in the narrow part of the upper stone, four holes being bored in it (parallel to the pivot) to let the corn pass through. The narrow

* Concluded from page 79.

part of the upper stone was hooped outside with iron, and holes cut in it into which wooden bars were inserted to turn it round; this being done sometimes by men, sometimes by asses. The corn was placed in the hollow portion of the upper stone, passed gradually through the holes in the iron socket, was ground between the surfaces of the stones, and finally fell into the groove round the base. Several loaves of bread were found in the different ovens; they are flat, about 2 in. deep and 8 in. diameter, and sometimes have had their form given to them by a mould.

The houses of the higher classes are divided into two parts, in accordance with the domestic customs of the Romans, and their double life; the first being public, the second private. The public part comprised the vestibule, or prothyrum, atrium, alæ, fauces, and tablinum; the private, the peristyle, cubiculæ, triclinia, pinacoteca, biblioteca, exedra, &c. The vestibule or prothyrum was a long narrow passage, about 6 feet wide, which led between the shops on either side to the atrium or hall; sometimes, though rarely at Pompeii, a small porter's lodge was provided on one side of the vestibule. The atrium was the largest room in the public part of the house, and it was here that the owner received his clients or supporters; in the smaller houses of those who were clients themselves, and therefore waited on others, this atrium served as the common resort of the family. It was a large apartment roofed over, with an opening in the centre called compluvium, towards which the roof sloped to throw off the rain-water into a shallow marble basin on the floor, called impluvium. Of these atria there were five kinds:—1. The Tuscanicum, or Tuscan atrium, the oldest and most commonly found in Pompeii. The roof was supported by four beams crossing at right angles, the included space forming the compluvium. 2. The tetrastyle, or four-pillared atrium, similar to the last, except that the beams of the roof were carried by columns, one at each corner of the compluvium. 3. The Corinthian atrium, had a greater number of columns round the impluvium, which was in consequence larger. 4. Atrium displuviatum, had its roof inclined the opposite way, so that the rain was thrown off towards the outside. 5. Atrium testudinatum, which was roofed over entirely, without any compluvium or impluvium: this kind existed only in the poorer houses.

Of course none of the roofs exist now in Pompeii; all have perished. Such restorations as one sees of them, therefore, are made from descriptions by various authors, and from representations in painting found on the walls. The roof round the compluvium was edged with ornamental tiles called antefixæ, and at the corners lions' or dogs' heads to carry the rain-water, or throw it into the impluvium. The open space was sometimes shaded by a veil, to diffuse the light and moderate the height. On the sides of the impluvium, facing the entrance vestibule, was generally a small marble table, and in front of it a figure in bronze or marble, holding a vase or a flower, from which water poured into the impluvium, this figure being carried on a pedestal or foot.

The floor was paved in mosaic, or ornamented by small squares of marble set in cement, at regular distances apart. Round this atrium were several rooms. 1. Alæ, or wings; small recesses for conversation. 2. Cubiculæ, or sleeping apartments, generally set apart for visitors, or for the male portion of the family. 3. Tablinum, a large room facing the vestibule, always opening into the atrium, and sometimes into the peristyle beyond, without any wall or separation. Curtains were probably drawn across this room on either side. At Herculaneum have been found some iron rods, to which such curtains might probably have been suspended; this room contained the family archives, statues, pictures, &c. On one side of this tablinum was a small passage called fauces, which admitted of transit to the private portion of the house without crossing the tablinum. In the private portion of the house were—1. The peristyle, which resembled the atrium in plan, but was larger, and always surrounded by a colonnade, the centre space open to the sky, with flowers, shrubs, and fountains in it. 2. Cubiculæ, or bedchambers: these were very small and inconvenient, entirely out of keeping with our modern notions; but as the Romans spent all day in the open air, they only required sufficient room for a bed to sleep in, their ablutions being performed either at the public baths or in private ones attached to all the larger houses. 3. Triclinium, or dining-room, the name being derived from the three couches which encompassed the central table on three sides, leaving the fourth open to the attendants. The size of the rooms and their number, of course, depended on the wealth of the proprietor. They did not give, however, very large dinner parties, or, when doing so on special occasions, used the atrium. the impluvium being boarded over. At their feasts the guests lay with the upper part of the body reclined against the left arm, the head a little raised, and the back supported by cushions; they used knives and spoons, but picked up their food generally with the fingers of their right hand. If ladies were admitted, they generally sat on the couches. Their meals seemed to be somewhat similar to the French repasts now-a-days, begining with the promulsio or stimulants to the appetite; then courses of meat, fish, flesh, and fowl, and finally dessert. The wine was kept in large amphoræ, or jars, in earthenware, about 2 ft. 6 in. high, of which many are found now in Pompeii. The jars were inscribed with the name of the consuls in office at the time of the vintage from which the wine was made. Æci, or halls, were large apartments richly decorated, sometimes looking out on gardens; they constituted the ladies' drawing-room. Pinacoteca, or picture-gallery, for easel pictures, of which, however, there were very few. Biblioteca, or library, a small room; very little space being required for the papyri, or rolls of manuscript, which were taken and read in the Exedra, a room generally used for study or conversation. Larenium was the chamber devoted to the Lares, or household gods. Xystus, or garden, only found in the larger houses. In some of the larger mansions, a special portion of the house was set apart for the female branch of the family, and termed the Venereum. The kitchens were very small, the cooking being done by charcoal fires, as it is now in some parts of France and Italy.

The upper floor of the house, as I have said, was occupied by slaves; there was also sometimes a solarium or terrace, adorned with flowers and shrubs, with trellis work, where probably the evening meals were taken in the summer months. These apartments constituted therefore the various requirements of a Pompeian house. I will now take one or two examples of the more important in Pompeii, in order to note their general arrangement or peculiarities.

The house of Pansa is one of the largest and most interesting in Pompeii. Its exterior is occupied on three sides by shops, one of which communicated with the house, and therefore we may suppose was kept for the sale of the produce of Pansa's estate. Another shop (from the mills and oven) belonged to a baker. There were also three separate small houses attached to it. The principal entrance is decorated with two pilasters on either side of the doorway; the vestibule is paved with mosaic; thence follow the atrium, two alæ, six cubiculæ, tablinum, fauces, peristyle, ornamented with sixteen Ionic columns, painted red one-third up, the rest fluted; four cubiculæ or sleeping chambers, two triclinia, a splendid æcus or hall facing the garden—this latter half the size of the mansion—a servants' hall, and kitchen. In this latter was a curious painting, representing a sacrifice to the Lares, who are personified by two serpents near an altar; representations of different animals and fish are also painted round. Serpents were looked upon with great reverence, and were considered as creatures of good omen; they were of a harmless character, and thoroughly domesticated, the ladies putting them round their necks, like a boa, in hot weather. They became at last almost a nuisance, like cats, from their large increase in numbers, no one daring to kill them.

The house of the Tragic Poet, though small, is especially remarkable for its paintings: in the vestibule was the celebrated mosaic of the "Cave Canum," copied in the Pompeian court of the Crystal Palace. In the triclinium was the celebrated fresco of Leda presenting to her husband Castor, Pollux, and Helen, as new-born birds in a nest. The peristyle is terminated by a wall, on which was painted a view of an imaginary garden. The house of the Centaur, or of Castor and Pollux, is of considerable size, and consists of two distinct houses, separated by a peristyle common to both. This house has an atrium of the third variety, with twelve Corinthian columns round it. In it were found two highly decorated chests, lined and bound with iron, which still contained a few silver and gold coins that had escaped the attention of some individuals who returned and made excavations after the eruption. They were unfortunate enough to miscalculate their distance, and arrived in the room by the side of the atrium, so that they had to penetrate the wall and the bulk of the chest before they could arrive at the treasure it contained. In the house of Sallust, on one side of the vestibule, is a large shop for the sale of liquids, which opens on to it; on the other side a large hall, an unusual feature. This house has also a venereum, a kind of harem, set apart for the female portion of the establishment. The house of the Coloured Capitals has a second peristyle, surrounded by a long range of twenty-four columns. Two other plans of newly excavated houses which I have sketched are curious, one called the house of Sirricum. The irregularity of its peristyle is the chief feature about it: from each of the columns also projects a small bronze water-pipe, forming with the fountain and waterfall in the marble tank a pretty system of ornamental waterworks. The other plan is of a small house, known as that of the "grand balcon;" the upper part of the house, viz.—first floor—projects forward over the street, and is carried by wooden brackets or cantilevers. The first-floor rooms here are very richly decorated. There is one other house of importance I have not yet described, "the villa of Diomede." It is one of the most extensive private houses, and more especially interesting as a suburban villa or residence. The house is built on the side of a hill, so that there are as many as four different levels; first and ground floors, basement, and cellars. It is one of the few houses in Pompeii which has a porch in front. There is no atrium; you enter the peristyle from the prothyrum; round it are triclinia, several cubiculæ or bedrooms, one of them elliptical in plan, with an alcove; a complete set of private baths, with court and portico, apoclyterium, frigidarium, &c. Also a room in which a large collection of robes were found; a gallery lighted by windows, looking on terraces; library and reading-room. Stairs lead to the apartments beneath, which seem to have been used by the family; they were situate on the basement floor, and looked out on the garden at the back of the house. They are, perhaps, the only apartments in Pompeii in which the ceilings remain; they are vaulted and painted with fancy arabesque decorations. Large terraces surround the garden, under which are shady porticoes, most delightful retreats in summer. In the centre of the garden was a piscina or fishpond, with *jets d'eau*, and a kind of arbour with columns, on which probably were trellis work and vines. Under the portico, and lighted by loopholes at the level of the ground, are galleries, probably used as cellars, from the large collection of amphoræ discovered there. No less than seventeen skeletons were found in this cellar, chiefly of females, who had taken refuge there during the fall of ashes over the city, whilst the men had taken to flight. Two of the skeletons were children, whose blond hair and texture of dress were still apparent. By the garden-gate were found two skeletons, one presumed to be the master of the house, with a collection of coins near him, and the key of the gate in his hand; the other probably a slave, beside whom were found several silver vases.

Architecture and Decoration.

Nearly the whole of the architecture of Pompeii betrays a Greek feeling in its mouldings and ornament; and although under the domination of the Romans, their architecture was gradually introduced, especially in the size and form of the public monuments and temples, still a certain refinement and beauty existing in them induces us to believe that, even if not by Greek, certainly they were not executed by Roman artists. Whilst the sections of the curved Roman mouldings were always portions of a circle, those at Pompeii seem to have been traced by hand, or approach more to the curves of conic sections; and yet, notwithstanding the resemblance in feeling to Grecian work, the results are so different that one is at a loss to account for it. To take the Doric column, for instance, which in the latter period of Greek supremacy reached a proportion of only 6½ diameters, here in Pompeii it falls to 8 or 9 diameters without any apparent transition. It is true that in the latter city they supported light weights, such as terraces constructed of wood only: in all other particulars the Pompeian Doric column fulfils the conditions of beauty in the Greek order, having no base mouldings, a simple capital, and ornamented with twenty flutings.

Again, the width of the volutes of the best Greek Ionic caps is equal to 1½ the lower diameter of the column, whilst in the Pompeian they are only 1⅙. The Pompeian Ionic cap has also another peculiarity in the difference of the form of the echinus moulding. Now the Grecian echinus is narrow and deep in form, like an egg with its shell around, and what is usually called the tongue, more like the head of a lance. In the Roman examples the egg is broader, the lower portion semicircular, the shell more spread out, and the tongue between takes the form of the barb of an arrow. In the Pompeian echinus however, the egg is extremely small, and the shell has an ogee form; the tongue is similar, but wider than the Greek.

The capital of the Corinthian order, like that of the Ionic, is smaller in proportion to the column than either the Grecian or the Roman varieties; its leaves resemble more those of the cabbage than the acanthus; and, as if to return to the original natural type from which it probably was copied, the volutes or spirals resemble more the natural tendrils of a plant, than the conventional form of them in the Greek and Roman caps. The temple of Vesta, or Tivoli, near Rome, has a similar capital, and it has been copied in this country in the Bank of England, designed by Sir John Soane.

There are no relics of the Classic period more interesting than the terra-cotta ornaments which are found in such abundance, and which give us an insight into the architectural decoration of the domestic and less monumental buildings. It has often been a matter of some inquiry whether this perfection of detail, these subtle proportions of the Parthenon and other buildings, only but lately discovered, and which we can scarcely now lay down by mathematical rules of the greatest complication, but which with them was instinctive and the result of highly-trained minds and eyes, whether the smaller buildings were designed and carried out with the same care; and I think that amongst other proofs these terra-cotta relics show us that they were not; for, although they show artistic feeling and taste in the highest degree, they are comparatively clumsy and rudely made; and I cannot help thinking, that now we have arrived at such mechanical perfection in the manufacture of these articles in terra-cotta and brick, a careful study of some of the old Pompeian and Roman work to be found in the British Museum and elsewhere, will greatly assist the architect in finding out the secret of their artistic beauty and effect, in order to instil a similar feeling into our modern work with a clear distinction of that kind of ornament which is best represented in the material. Time will not permit me now to enter into further details about the architecture, as I have yet a word to say on the mosaics and fresco painting.

Of the mosaics I shall say but little; those of Pompeii generally consisted of black frets on a white ground, or white on a black ground; sometimes they were executed in colour, as in those found in the Villa of Diomede. The formation of pictures in mosaic was originated by the Greeks, who arrived at extraordinary perfection in their manufacture; they are works of enormous labour and expense. Rougher and coarser kinds of mosaic are also to be found in Pompeii; one kind forming an ornamental covering for columns in the place of stucco and paint: a second kind consisted of irregular-shaped pieces of marble and stone, stuck in cement, and not smoothed down to an even surface, with shell-work. The Great Fountain is a good example of it, which latter is more remarkable for its singularity than good taste.

The fresco-painting of Pompeii is very interesting to us, having but little acquaintance with that kind of work. The Pompeian fresco-painter used some kind of resin, which he mixed with the colours in order to give them tenacity, and render the impasts of their tints glutinous: wax was placed afterwards on the painting to fix the colours and brighten their tone. The plaster consisted of seven coats, three of sand and four of marble-dust, each successive coat being formed of thinner and finer stuff than the last. The several coats were laid one upon the other without allowing any one to dry. The painter then commenced by tracing with a graver or style the principal lines for ground tints. He then indicated with the same graver the figures of arabesque, and proceeded to fill them in with colour, the wall being still moist. As however the work proceeded, the wall would naturally be drying, and hence the amalgamation with the surface would be less complete. You will understand from this description of the system employed in painting, that the putting on of the colours had to be done with great celerity, that there was no time for study of composition or effect: in consequence, their painting must be looked upon as decorative rather than finished drawings or paintings. Of course, they had the power of cutting out the plaster in any part and forming it again, but this was rarely done.

From careful observations of the different frescoes from Pompeii and Herculaneum, I was able to perceive that there existed two or three different styles, which might in fact be expected from the changes of people to which the town has been subjected; hence the Etruscans, or Cumæans and the Greeks, naturally must each have brought in their special styles; and, in later date, the Romans. To draw a clear and definite line of distinction, however, would be very difficult with so few illustrations as I have here. Without regard to style, however, I might class the paintings in three divisions:—1st and highest, The pictorial representation of groups of figures: which I would call the ideal based on nature. 2. The representation of natural foliage, plants, &c.: the real based on nature. 3. The representation of imaginary perspectives of imaginary architectural feature: the ideal based on conventionalities, fantasies, and conceits. The first is certainly the most important, because it gives us a glimpse of what the ancient Greek paintings may have been; for, judging the Grecian sculpture and architecture in comparison with the Pompeian, we may draw our conclusions as to what the Greek paintings were in comparison with those found at Pompeii; and the paintings of Greece may be fairly supposed to have been as superior to the paintings of Pompeii as the Grecian sculpture and architecture surpasses the Pompeian. The Pompeian paintings, therefore, are extremely interesting to us in that light; they rank, however, themselves as paintings of the highest class. I have, I am sorry to say, but few illustrations of them here; I must refer you to the works of Sir W. Gell and Professor Donaldson, and also to the Pompeian Court of the Crystal Palace, in proof of what I say.

The composition of the figures, the elegance of their movements, and power of drawing, are most remarkable, especially when we take into consideration the hasty manner in which it was necessary they should be executed. The paintings under the second head are curious, as contradicting the assertion often made, that the ancients never copied nature directly, always resorting to some conventional treatment of it. Nothing can exceed the beauty and simplicity with which the natural foliage of trees and shrubs is depicted; whilst our modern artists would occupy whole hours in the painting of an apple, for instance, the Pompeian in as many minutes produced the same, with at all events sufficient indication and power to last eighteen centuries. This kind of decoration was generally employed at the further end of the peristyle, where it was supposed to represent a garden beyond. I may mention that near Rome, at the "Prima Porta," has been discovered a chamber painted in this style. I was fortunate enough to get access to it when in Rome last year, and was astonished at the brilliancy of the colours and wonderful execution.

To the third class of paintings I looked forward with considerable interest and curiosity, in the hopes of being able to discover in these architectural perspectives traces of a style of architecture in which metal would form the chief material; but I am sorry to say that I could discover little in it but what might have been the composition of imaginative minds; and my chief reason for disbelief in it is, that it contains all those details, such as architraves, friezes, with triglyphs and cornice, which belong to stone architecture, and are quite unfitted for the true use of iron. So that, even supposing that these compositions of attenuated columns, &c. were copies of the terraces which existed on the tops of the houses, we have nothing to learn from them more than we can do ourselves, and it is the archæologist rather than the architect who would feel interest in them. However, be they what they may, it is impossible not to admire their wonderful execution, and the grandeur and apparent size they give to the apartments whose walls they occupy.

And now a few words on the general system of decoration. The walls appear to have been divided into three parts in height, the lowest about 3 feet high, constituting as it were a dado; the second (according to the height of the room) some 9 feet or 12 feet above the dado; and the third up to the ceiling. The lowest was the darkest in tone, the second intermediate, and the uppermost the lightest of all, generally white: sometimes there were only two divisions. Hence, if the dado were black, the middle portion would be red or yellow, and above white. If the dado was red, the middle portion would be yellow or blue; and if the dado was yellow all the rest of the wall would be white. The object of this was probably that the lower portions of the wall were most likely to be soiled, and therefore the darker they were in tone the better; which may also account for the singular idea of painting the lower portions of the columns red or yellow. The colours I have given are, of course, only the grounds on which were painted various designs.

Panels or compartments were always executed in simple and unmixed colours, such as red, yellow, blue, &c. Sometimes the panels were of the same colour; sometimes varying, or relieved by borders or a white background, with architectural perspectives. Nearly always the centre of the panels is occupied by single figures or groups in pale colour on the dark background, or in small frames or medallions. The number of accessory ornaments which accompanied these decorations were composed of an infinity of garlands, borders, frames, standards, panels, friezes, and other details, of which it is difficult to understand the meaning, except that, æsthetically speaking, they are pretty.

Towards the latter days of Pompeii, the rage for colour seems to have taken such possession of the people and their artists, that they sacrificed form to it in every possible way; hence we find the beautiful mouldings of the earlier ages covered with stucco, and painted with as many broad surfaces as possible for the display of colour; and the simple and elegant columns, originally Doric, of the temples and porticoes made to lose all their elegance and beauty, being converted into pseudo-Corinthian by the addition of numerous coats of stucco, and then painted. Another kind of decoration is that whose origin was probably derived from the third class of paintings before alluded to. It consists in the representation in stucco relief of these architectural perspectives, and was employed in places where the rain or moisture would affect paintings: it was formed whilst the stucco was wet, partially with the plasterer's trowel, partly with moulds.

In conclusion, I think there is a great deal to be learnt from the plan of the private houses in Pompeii; for although our climate be very different, there are still certain principles which it would be well to bear in mind, such as the simplicity of their arrangements and the beautiful perspectives they give. I am not sure if in our country mansions and villas those peristyles and courts could not be well introduced, covered with glass if you will, and in the centre of them fountains and shrubs. The plans and details of the public baths are extremely interesting, because it happens that they are being introduced into England at the present time.

Our institutions, religious and civil, of course, would clash somewhat with the public monuments and temples; but we cannot help, however, looking with envious eyes on those grand forums and public places, so necessary to health in a large metropolis, and affording so great an opportunity for improving the tastes of the people by the display of national monuments of a high class.

With respect to the fresco-paintings—perhaps the most interesting portion of my subject—I may as well say that, on strict reasoning, I cannot advocate all Pompeian work as based on a healthy and true principle. Whenever reason however enters into the question, it is very difficult to lay down any laws. The doctors themselves do not agree; for whilst one, on strict scientific principles, advocates diaper patterns, another cries out for common sense, and suggests, "as a truthful idea, the painting of lovely children jumping through vine-leaves."

The Pompeian decoration certainly arrives at great perfection in the objects its artists probably had in view, viz., that of pleasing the eye with elegance of form and beauty of colour. If we can satisfy these demands, it matters little the means by which we arrive at it. I can only recommend, therefore, to architectural students a careful study of the principles on which such perfect harmony and contrast of colour are obtained in the fresco-paintings of Pompeii: their own hearts will dictate to them the best means of displaying it.

IRRIGATION WITH TOWN SEWAGE.

By George King.

Irrigation is a practice of very great antiquity, and one of which descriptive records are to be found in various ancient writings. It has been and still is practised, in one form or other, in most parts of the world. Egypt, China, India, &c., all bear witness to its extensive adoption. In Lombardy it has been carried out upon a large scale for about 800 years. It is also much practised in various parts of Italy, Belgium, and France. To the Romans is generally attributed the introduction of irrigation into England, where it is extensively adopted in the counties of Wiltshire, Hampshire, Gloucestershire, Somersetshire, and Devonshire. The valley of the Wyley, from Salisbury to Warminster, is an almost unbroken series of irrigated meadows, extending about twenty-two miles in length, and covering an area of about 3000 acres. The practice, however, is not exclusively confined to warm climates; its great success in Scotland has become proverbial, and the still colder climates of Sweden and Russia bear testimony to its value. The time is probably not far distant when Australia and Africa may be greatly enriched by judicious irrigation.

Although the results of ancient irrigation have been great, they diminish in importance when compared with the modern irrigation with town sewage. Of this system Edinburgh offers a striking example. Although situated in a high northern latitude of 56 deg., with a mean temperature of 47 deg., and having in parts some a sterile soil, and other physical disadvantages, these meadows are probably without a parallel for extent of land operated upon and for profits realised. In treating the subject of the paper it is proposed to describe these meadows, noticing separately the different portions which lie in various directions round Edinburgh, there being some peculiarity in each set of meadows, either as regards the mode of applying the water, the manner of disposing of the produce, or the prices made by the different methods of sale.

THE CRAIGINTINNY WATER MEADOWS.

The entire estate originally comprised five farms of various sizes, called Craigintinny, Fillieside bank, Southside bank, Wheatfield, and Piersfield, amounting in all to a quantity of about 500 acres. The land under irrigation has a north-western aspect, and lies exposed to the sea in that direction without any shelter. On the south-western side, where least needed, it is screened by trees and hills. About sixty or seventy years since the portions of Fillieside farm known as Fillieside old meadow, east and west of Old burn, as the original watercourse is called, were almost worthless, being formed of sand hills and hollows as left by the sea. The sand lies upon a strata of hard clay-like silt, also the washings of the sea. The portion called Blackside Meadows was arable. It consisted of a tenacious clay, very difficult to work, but with well manuring and a suitable season producing a good crop, and in an unfavourable season totally failing. The parts known as Fillieside upper meadows, Burniward's meadows, Lockstrand meadow, Jenny's acre, the Garden lot, and Fillieside braes, were arable, similar to the parts known as North field, East field, and South field, having a fair average workable soil, inclining to clay; the same may be said of the Craigintinny meadows, which nearest the house are alluvial soil, but along the road they partake of the same nature as the Blackside meadows. The part known as the Engine meadows was taken, a portion from each of the Southside bank farm, the Craigintinny farm, and the Wheatfield farm, and is in nature very similar—a good arable soil, both for working and crops, but lying upon a dry, hard, gravelly subsoil, and requiring much moisture, and which, in pasture, would be very inferior land. All the arable land above the Engine meadows is a very good deep soil, suitable for any crops. The Sea meadows, on each side of the Leith turnpike road, were, forty years since, a mass of sea sand, totally worthless. This piece is part of the land formerly called the Figgate whins, which was notable for its barrenness. Previous to 1762 the site of Portobello, which joins Leith parish at this point, and the surrounding lands, were a moorish, furzy waste, of no value whatever for agricultural purposes, and mainly distinguishable from a desert by the presence of one human dwelling. In 1762, however, these lands were let at about £11 for several hundred acres. A few months after they were sold for £1500. This land is now the site of the favourite watering-place, Portobello, containing in 1851, 1449 houses, and 6932 inhabitants.

Having briefly noticed the condition of the land previously to the application of the water, we will now consider the method of applying the water, and the cost of the operation. The peculiar construction of the ground upon which the city of Edinburgh is built, comprising ridges and gulleys, tends to throw a great portion of the sewer-water in a direction exactly opposite to the river called the Water of Leith, which skirts Edinburgh on its north-western side, in its course to the sea at Leith. The greatest part of the sewer-water, therefore, wends its course to the sea in the direction of the Craigintinny estate, through the village of Restalrig, whose sewage it receives as well as that of the village of Jock's Lodge, the large engine depôt and cokeing establishment of the North British Railway, and the Piers Hill cavalry barracks. In its course the sewage burn receives very little spring water, and may, therefore, be considered as purely sewage, except in wet seasons or from heavy storms, and even then the area which it drains is too limited to cause its banks to overflow; therefore the water in all seasons is perfectly under command. There was formerly a water-wheel at the Fillieside farm-steading, which was turned by the sewer water; this probably suggested the idea of carrying the water upon a level from that point to the opposite end of the farm, for the purpose of irrigation, which gave full control of the water over all that side of Fillieside farm known as Fillieside old meadows, west of Burn. The Fillieside farm at that time—about the year 1800—was occupied by a tenant of the name of Wright, to whom is due the merit of commencing the irrigation. He conveyed the water to the opposite end of the farm, and laid out the irrigation upon a plan suitable to the shape of the ground. Where the land lay with a fall one way he adopted the pane and gutter system, but where it was more uneven he employed the catch-water system. By these modes he irrigated the whole of that portion of the farm, about 30 acres. Having got this part into working order, Mr. Wright proceeded to operate upon the Fillieside old meadows, east of Burn, and in order to have a full command of the water he cut a carrier alongside the main farm road to the extreme part, known as Blackside meadows, round which the carrier takes a circuit to Fillieside farm-house. This carrier is about forty-eight chains in length, and by the road side is about 6 feet wide and 3 deep. The soil from this cutting probably went to fill up hollows in the part about to be irrigated. This portion of the irrigation is laid out similarly to the former, and was much more expensive. In addition to the expense of carrying on the works, another, and far more formidable one exists, namely, that of purchasing stock to consume the immense quantity of grass produced, for the system of rouping had not then been brought into operation. These and other causes obliged Mr. Wright to relinquish the farm before he had finished this part of the irrigation, and, there being no law to the contrary, the whole of his outlay became the property of the landlord. The farm was then let at a greatly advanced rent to Mr. West, who completed the irrigation. In time another change occurred in the occupancy, and ultimately the proprietor, Mr. W. H. Miller, took the entire estate into his own hands for the purpose of carrying out a more general and scientific mode of irrigation. He employed an engineer, who took levels from the point at which the sewer water enters the estate, which gave an elevation of about 12 feet higher than the level carried along by the farm road by Mr. Wright; this carrier is called the high-level, it branches off from the old Burn in a northernly direction between Lockstrand and Burniwards meadows, and is carried along an embankment about 9 feet high, and passes by Fillieside upper meadows and Fillieside braes until it reaches the extreme end of the estate. A branch also strikes off from this level about three-fourths of the way through Fillieside upper meadows, and then diverges to the south. The high level on the opposite side of the Old Burn, takes a course somewhat parallel with the main farm road to the extreme end of Craigintinny meadows; it then turns suddenly towards the north, and, by means of an embankment and aqueduct, crosses the farm-road, and continues about two-thirds of the way across the Blackside meadows, when it turns to the west and runs nearly to Fillieside farm-house. Another branch runs from the point at the end of Craigintinny meadows in a south-eastern direction by Southside bank meadows to the London-road. The fences were all removed, and the land taken irrespective of pasture or arable; the different meadows were, of course, formed after the carriers were set out. The Fillieside braes is a steep bank lying between the high and low levels, over which the water flows by its natural fall.

The Fillieside upper meadows are pane and gutter artificially levelled, and are all formed upon inclines, the floating trenches spreading the water on, and the draining trenches carrying it off to the low level, where it is used a second time, if required.

The Lockstrand meadows are irrigated partly from the same level and partly from a carrier on the opposite side, and are also pane and gutter; the waste water is conducted under the embankment to the Fillieside upper draining trench.

The Burniwards meadows, running along the north side of the main farm-road, are irrigated by a small carrier alongside the road, and drain into the same trench as the former.

The Middle Craigintinny, the Wheatfield, and the Tringular meadows, also pane and gutter, on the south side of the road, are irrigated from the high level, the waste water draining off into the low level

The Craigintinny meadows are a continuation along the south side of the road, also pane and gutter, irrigated from the high level, and drain into the low level; they extend to where the carrier turns right and left. The Blackside meadows are well planned and executed, pane and gutter, irrigated from the high level, after it has passed over the farm-road by means of the aqueduct; the northern side falls towards Fillieside meadows, the southern side towards the road; both sides drain into the low level. Jenny's acre, and the Garden lot are irrigated from this level, and drain into the Old Burn.

Southside bank is the strip between the high and low levels, leading from the end of Craigintinny meadows, in the south-eastern direction, to the London-road. This is a steep bank, very similar to Fillieside braes, and is irrigated in a similar manner. This bank, as also the Fillieside braes, was probably at some remote period the sea boundary, as all the land between them and the Firth of Forth is sea land.

The Sea meadows were formed about the year 1821, and for this purpose a carrier was cut from the low level, at the point by the road where it branches off round the Blackside meadows; this carrier was continued up to the London-road. They are formed upon the same plan as the others, namely, open gutters and panes, but the ground required a great deal of levelling, and being intersected by the Leith turnpike-road, is laid out in two portions, called the Sea meadows and Upper sea meadows; the latter, lying on the south-west side of the road and next the carrier, were formed first, and the water runs from them into a carrier on the north-east side of the road; but as far the largest portion of the Sea meadow lies on that side of the road, there are three sluices which deliver the water by means of inverted culverts under the road, where the water rises to the required levels and flows along the carrier right and left, according to the fall of the ground, from the culverts to the extreme ends of the meadows, the south-eastern end being much wider than the other; extra carriers run across about the middle, to insure a supply of water to the lower parts.

The Engine meadows were formed in 1850, and occupy the entire southern portions of the irrigations, from the Sea meadows to the extreme western end, and are wholly on the south side of the high level; the ground is formed in open gutters and panes similar to the others, and are called Southside bank east, Southside bank west, and Wheatfield new. These meadows are irrigated by means of a steam engine of about 8-horse power, which also works thrashing and other machinery. The water is conveyed by a carrier from the high level opposite the Upper Sea meadows towards the centre of the part called Southside bank east, and from that point by a drift or tunnel to the engine well, it is raised by the engine about 30 feet, and runs through 16-inch earthen pipes under the farm-road, from thence it is conveyed by the carrier to the extreme western end of the irrigations, called the Wheatfield new meadows. Another carrier diverges off from this one in a northern direction along an embankment about 7 feet high, nearly to the opposite side of the Engine meadows, it turns along the high ground right and left, and the water flows out of each of these branch carriers on both sides. Another carrier was cut on the opposite side of the farm-road in a north-eastern direction to the Southside bank meadows. The whole of the waste water from the Engine meadows runs into the high level to be again pumped up by the engine.

From a report on the Craigintinny Meadows made by Mr. William Lee in 1851, at the instance of the General Board of Health, it appears that the Fillieside old meadows, containing 53a. 3r. 9½p., cost £500; the New meadows, containing 96a. 0r. 5½p., cost £1300; the Sea meadows, containing 40. 3r. 11¾p., cost £700; and the Engine meadows, comprising 59a. 3r. 16¼p., cost £2000; making a total of lands irrigated 250a. 2r. 2¾p., and a total of money expended in so doing £4500.

It will be seen that the cost of forming the Engine meadows was £33 6*s*. 8*d*. per acre. This includes the cost of conveying the water to the engine, and the cost of the engine itself—the former £1000 and the latter £250—the actual cost of forming the ground was therefore £12 10*s*. per acre. There are two watermen employed, one by day and another by night, one being always on duty. There are never more than ten to fifteen acres under irrigation at a time—the whole is divided into districts which are operated upon in succession. It occupies about twenty-one days to go the entire round of the irrigation. The first part is then commenced with again, and so go the rounds of the irrigation during the summer months. In the winter the irrigations are only applied occasionally, making in all about 224 days' irrigation out of 365. About half the city of Edinburgh, but by far the most densely populated part, having from 80,000 to 90,000 inhabitants, discharges its sewage in the direction of the Craigintinny estate, and the average quantity of sewage water flowing is estimated by Mr. Lee at 220 cubic feet per minute. The following table will show the approximate quantity of water flowing, and the quantity actually applied in the irrigations during the 224 days it is in operation:—Per day 316,800 cubic feet, = 9360 tons weight; per year, 115,711,200 cubic feet, = 3,418,740 tons weight. Calling the part irrigated 250 acres, gives as follows per acre:—Per year, 462,845 cubic feet, = 13,675 tons weight. Quantity actually applied in irrigation per 224 days:—284,047 cubic feet, = 8392 tons weight.

The large quantity of water flowing, as compared with the number of acres irrigated, giving 8392 tons weight per acre per annum, or about 80 inches in depth, without allowing for storm water, and what runs to waste the 130 days the irrigations are suspended, is clearly much more than is required for irrigation. In many parts the ground is exceedingly soft and yielding, but there is a firm road, not irrigated, to each rouping lot. All these roads, except the main stone farm-roads, as well as the floating and rouping trenches, are measured in as appendages to the lots to which they adjoin, so that no land is lost to the proprietor on account of those conveniences.

Mr. Lee estimates the annual expenses of applying the water to the old meadows at £48 for the 224 days irrigated, and the annual working expenses of the Engine meadows at £117 12*s*. The latter, of course, includes the working of the engine, the watermen's labour, and other incidental expenses. This is calculated at 10*s*. per 12 hours, with coals at 6*s*. per ton; but as the engine works night and day it is £1 per 24 hours. It raises about 500 gallons per minute, by means of two pumps of 15 inches diameter. This gives £1 19*s*. 2¼*d*. per acre as the cost of applying the water by steam power, and 5*s*. 0½*d*. per acre by gravitation.

Next as to the results obtained by the application. The cut of the grass is let annually by public roup or auction. In 1859 the roup took place on the 31st March, and the cutting commenced on the following day, with very good crops. The effect of the grass on the cattle is very marked and highly favourable. The meadows increase in richness, and consequently in value, every year; the grass not only improves in quality, but gradually becomes thicker; five or six good crops are cut in course of the season, five weeks is sufficient time to allow between each cut; if too long a period elapses between the cuttings the grass becomes lodged and rotted on the ground, and if cut in that state is much longer in starting again. In some of the best of the old meadows eighty tons per acre have been cut in the course of one season; an acre of such grass will keep eight or ten cows through the summer, and the prices obtained in 1859 ran from £20 to £35 per imperial acre for the old meadows collectively.

In 1860, owing to severe weather, the first roup of the Craigintinny Meadows did not take place until the 28th April, a fortnight later than had ever been before, and a month later than in 1859. Even then, there were large patches where the grass was cut last, and had not sprouted again to cover the ground before the first severe frost set in on the 20th October; where vitality seemed entirely destroyed the ground was in these patches covered with a crust of dead bog, without a living blade of grass upon it. The lots not being all equally forward it was determined to have a second roup of the later lots; the few first lots were therefore taken promiscuously here and there amongst those intended for the second roup. It appeared these lots had not been cut so immediately before the severe frost set in, consequently the ground was not covered and protected from the effects of the frost.

Having disposed of these odd lots, they commenced with the Sea meadows below the Leith turnpike-road. Lots 1 and 2 are very much acted upon by the sea, as they commence at the end of the sea-wall built by the railway company, and will soon apparently be washed away. These lots were, on that account, not offered. Lots 3 and 4 are similarly affected, but not to the same extent. These two lots now form one, and were let at a comparatively low price—£18 per acre. Lots 5 to 63, which comprise the whole of the Sea meadows, ran pretty regular, ranging in price from £20 per acre the lowest, to £37 the highest. They next proceeded with the Upper Sea meadows, running from Lots 64 to 81: there were four lots which had suffered very much from the frost, and were reserved for the second roup; the other lots ranged from £22 5*s*. the lowest, to £40 5*s*. the highest. Burniward's meadows, consisting of nine lots, ranged from £28 15*s*. the lowest, to £33 10*s*. the highest. Fillieside old meadows, east side of Burn, from No. 30 to 59, excluding four damaged lots reserved for the second roup, ranged from £22 15*s*. the lowest, to £36 5*s*. the highest. Fillieside old meadows, west of Burn, comprising Lots 1 to 29, averaged rather more per acre than those east of Burn. The Fillieside braes, the Upper Fillieside and Lockstrand meadows, realised a great advance per acre above any of the others. This may be attributed to its being better land in nature, and better formed, being all in pane and gutter, with a good fall, there was not a failing patch, the grass was splendid, and fit to cut; several lots made over £40 per acre, and the three portions averaged over £35 per acre. It was a subject of remark that although the roup was a month later than the year before, the grass had let at from £2 to £3 per acre more, showing either a gradually increasing quantity, and consequent value per acre, or else an increased demand, requiring, if possible, an increased area under irrigation.

The second roup took place on the 18th of May; but the effects of the frost were still visible, and probably a great many of the lots would not regain their former vigour during the summer. To guard against a recurrence the time for cutting the grass is limited, by the conditions of sale, to the 10th of October; and under no pretence whatever is it to exceed that time. Previously to the year 1860 the time for discontinuing the cutting was 15th October, and then a few days of grace were allowed to the 20th October, the very day on which the severe frost of 1859 commenced.

The lots rouped were 57 in number and the price averaged a little over £25 per acre, which, to the seller, is probably less than the year before, but to the purchasers more.

1860, from May 18th to October 10th, equal 20 weeks 2 days.
1859, from April 18th to October 20th, equal 26 weeks 4 days.
£1 4*s.* 7¾*d.* per acre per week—20 weeks 2 days, equal £25. per acre.
£1 4*s.* 7¾*d.* per acre per week—26 weeks 4 days, equal £32 14*s.* 10½*d.* per acre.

Probably more than the average of 1859. It will be observed that nearly all the lots reserved for the second roup were upon the heavy clay land, in the centre of the irrigations, showing clearly that clay soil is much more injuriously affected by severe frost, and later in the spring growth than lighter soils, but as the summer advances it produces crops equally heavy, if not more so.

When the branch of the North British (at that time the Dalkeith) Railway was made, in the year 1834, a jury awarded that the railway company should pay £640 per Scotch acre, for the land taken in going through the Sea meadows, which they assessed at thirty-two years' purchase, on an annual value of £20 per acre, there was no severance, as the railway ran alongside the turnpike-road the whole of the way. Taking that as a data, and taking the annual value at £29 3*s.* 6¾*d.* per imperial acre, the 190a. 2r. 26¼p. at the present time represents a value of £932 17*s.* 4*d.* per acre, or £177,867; and assuming again that the annual value of the land before it was irrigated was £5 per imperial acre (quite a high estimate for it altogether at that time), would represent a value of £160 per acre, or £30,506, which deducted from the former leaves a balance as the increased value of the land by irrigation of £147,361, and that by an outlay of £2500; and it is somewhat remarkable that the railway company, requiring about four Scotch acres at £640 per acre, or £2560, actually paid for the whole of the irrigations. It appears that Mr. Miller, the proprietor of the meadows, would have given the railway company the land they required upon condition of their carrying the railway along the outside by the sea, as the railway works would have sheltered the meadows from the sea, but this they refused, as they would have had to construct a sea-wall about a mile in length; but it is probable they would have made a better bargain by accepting the offer, as they had to pay for a heavy lawsuit as well as for the land.

The Engine meadows are not nearly so productive as the older meadows. For this there are various reasons. In the first place, they have been made only ten years, and have not, therefore, had time for the irrigation to develope its effects, and the sewage having to be pumped by steam power the land probably does not get so much as it would if it ran over by gravitation; and the carrier having to run a long distance nearly upon a level, causes the heavier particles of the sewage to fall before it reaches its destination; the sewage is therefore weaker. And again, in forming the ground, due care was not taken to keep the best soil at the surface. In the Fillieside and the Sea meadows, where it was all sand, that precaution was not necessary. The same may be said of the Blackside meadows, which were all clay; but in the Engine meadows, where there was a good top soil with a gravelly hungry subsoil, the case is widely different. Another reason which operates seriously against the Engine meadows is, they had been shallow-drained with tiles, and in places, where the soil has been taken away, the water gets into the drains before it has done much good to the land. But another, and perhaps stronger reason than any, is that too much was attempted at once, as the land requires more water the first few years than it does after it has been well dosed with it. Had thirty acres have been taken instead of sixty, they would have been brought into working order, and the other thirty could then have been operated upon.

Mr. Brice has very judiciously broken up twenty-five acres of it, which will enable him to cultivate and enrich the weak parts where the soil was removed; and he can alternately lay down with Italian rye grass, which is more profitable for two seasons than old meadows; while this is going on he will be enabled to do as much for the thirty-five acres of meadow as he could before for the sixty acres, and when that is sufficiently enriched, he will be able to do the same for the remaining twenty-five acres. It takes some time to bring meadows irrigated with town sewage up to their maximum production—they continue increasing in richness every year for a long time before they reach that point; for instance, the Sea meadows in 1850 only averaged about £17 per acre, whereas, in 1860, they realised £27 13*s.* 6½*d.* per acre.

The time occupied in going the entire round of the irrigation is about twenty-two days, this is repeated about ten times in the course of the year, or about 224 days are occupied in irrigation; out of the twenty-two days it requires six days to irrigate the 35a. 0r. 30¾p. of the Engine meadows at present under irrigation, this being repeated ten times, take sixty days, or £60 to irrigate the 35a. 0r. 30¾p., or £1 14*s.* 1*d.* per acre, nearly seven times as much as the Old meadows cost by gravitation, a circumstance rather unfavourable for employing steam power where it can be avoided, unless upon a large scale.

The rouping of the Engine meadows did not take place until the first week in June, when the prices realised averaged a fraction over £16 per acre, which, allowing for the shortness of the time—from the beginning of June to the 10th of October, little more than four months, and that after the first and most valuable part of the season was over—was not a bad price.

Taking the Engine meadows at present under irrigation at 35a. 0r. 30¾p., and the price per acre £16, the results of the letting will be as follows:—

No. of Lots.	Name.	Quantities.			Price per acre.			Total amounts.		
		A.	R.	P.	£	s.	d.	£	s.	d.
10	South Side Bank East ..	5	3	38¾						
10	Do. do. do. West	6	1	19¼						
21	Do. do. do. do. ...	14	1	4¾						
12	Wheatfield New	8	2	19						
53	... ...	35	0	31¾	16	0	0	563	0	0
Average of Old Meadows		190	2	26¼	29	3	6¾	5,563	5	7¼
Total amounts		225	3	17¼	...			6,126	5	7¼

Assuming the foregoing data to estimate the value of the irrigation on the Engine meadows, which (as the part at the time in plough was to be laid down with Italian rye grass that season) is put at the quantity formed for irrigation by the engine,—namely, 59a. 3r. 16¼p., which, at £16 per acre per annum, represents a value of £512 per acre, or £30,604; and, taking again the value at £5 per acre before irrigated, represents a value of £160 per acre, or £5600, which, deducted from the former, leaves an increased value by the irrigation of £25,044, amply sufficient to justify an outlay of £2000.

The results obtained by the application of town sewage to these meadows is now brought to a close, and the facts and statistics clearly show that the late Mr. Miller, the proprietor, realised the sum of £172,405 by an outlay of £4500 in putting under irrigation 250a. 2r. 2¾p. of his land with a portion of the sewage of Edinburgh. It must be borne in mind that upon the irrigated lands no buildings are required, consequently no expenses arise from repairs, insurances, &c. It is also worthy of remark that no account has been taken of the benefits confered upon the arable portion of the estate by the application of immense quantities of sediment manure collected annually out of the large carriers during the winter.

Lochend Meadows.

These meadows are situate immediately behind the locomotive and cokeing establishment of the North British Railway, adjoining the village of Restalrig and the London road leading into Edinburgh: they comprise about thirty acres. That part lying north of the sewage burn is the property of the Earl of Moray, and forms a part of the Lochend farm. The part on the south side of the burn is held under lease of Sir James Montgomery, by Mr. John Brown, for a long term, and is underlet with the other parts; and the piece behind the church at Restalrig is part of the glebe land at Leith, and is also let with, and forms a part of, what are called the Lochend meadows, now in the occupation of Mr. Scott.

The Old meadows were formed by Mr. Baird, about the year 1790, and were the first meadows brought under irrigation with the sewage of Edinburgh. The whole is irrigated by gravitation, and a large portion of it is pane-and-gutter, but it has not been so scientifically formed as the Craigintinny meadows; the ground lies more in its natural shape. There are considerable swells about it, and in some parts the catchwater system is mixed with the pane-and-gutter, and some of it is much too flat; it is alluvial soil, almost black, and sometimes gets so rank that it has been taken away, a spit deep, and used as manure on the arable part of the farm.

These meadows get the use of the water on its way to Craigintinny meadows. It is, therefore, stronger than when it reaches them—indeed, it has been a matter of complaint that it was too strong, and there were no means of diluting it, therefore it did not answer so well. Mr. Oliver, who occupied the meadows some years since, made this complaint, and Mr. Taylor still makes the same complaint, but says it is better in that respect than it used to be, since Edinburgh has been more plentifully supplied with water. To remedy this, in a degree, a large pit or tank was made, through which the sewage runs, and which collects a large quantity of sediment, which is carted away to other parts of the farm.

From the fact that the Lochend meadows having about the same flow of sewage as the Craigintinny, which are about eight times the area, it might be expected that they have attained a much higher state of fertility; but, with the exception of one piece, which is very sound, with a good slope, and facing the south, such is not the case. It is found in practice that very little benefit—if not positive injury—is derived by the application of more sewage than is applied on the Craigintinny meadows—namely, about 8000 tons per acre per annum.

The part north of the sewage burn has a good aspect, and lays with a good fall, and is, therefore, the best part. It drains itself quickly, and is very sound. A large carrier runs along the upper side of this part to the extreme end; and a good stone road runs alongside the whole length of it, which serves all the lots.

The opposite side of the stone road is cropped alternately with Italian rye grass two years, and then early potatoes, after which it is sown again with Italian rye grass. This piece, comprising about ten acres, rises to a considerable eminence, and is irrigated by means of a water wheel worked by the sewer water, which pumps up a portion of the water after it has passed the wheel. The pump is of very simple construction, with four cylinders and two wooden levers, each end of which works one of the cylinders. The levers are acted upon by a crank direct from the water wheel, and, having alternate action, keep up a continuous supply of water through a 5-inch iron pipe, with hydrants every chain's length, until it reaches the top of the field. There are trenches cut along the slope of the field, upon a level from each of the hydrants, for the purpose of irrigation as well as rouping divisions.

This piece of land is a loose, gravelly soil, with a subsoil of sand to a great depth, which is in process of being carted away to Edinburgh for building purposes. Many of the carts sent for sand bring a load of rubbish to shoot down, to make up the ground. The sand pit extends across the whole piece. This land drinks up the water as fast as it is applied, for which reason gutta-percha hose is attached to the hydrants, as the water would not flow half-way from one trench to the next. It oozes out to the bottom of the sand pit perhaps 20 feet below the surface.

It was sown down with Italian rye grass in 1857, after a crop of early potatoes; and one crop taken off that autumn sold for £5 per acre. At the time of the author's visit, in 1859, the end of May, the second crop was being cut. The prices realised at the roup were, £35 10*s*. the lowest, to £38 15*s*. the highest, per acre.

(To be continued.)

ON CERTAIN METHODS OF TREATING CAST-IRON IN THE FOUNDRY.

By Zerah Colburn.

The short notice given me for the preparation of this paper, together with the fact of my almost constant engagements, must serve to excuse any apparent haste in the treatment of the subject, as well as the absence of diagrams. I had thought of writing upon iron founding, and to a certain extent I have done so, but the term "iron founding" would hardly include some things of which I shall now speak, and hence I have chosen the title already announced.

Begining with the plant of the foundry, something may be said of the cupolas and of the blast apparatus. The cupola furnace is still much the same as described by John Wilkinson, who patented it in 1792. His smelting furnace (and smelting is from the Dutch word *smelten*, signifying melting only, and not necessarily the extraction of ores) was, to use his own words, "made very low, about 10 feet high, of cast-iron plates bolted together, and lined with fire-brick." A strong blast was introduced through one, two, or more tuyeres. In 1820 one William Taylor patented the use, in blast furnaces, of several tuyere holes, at various heights and in different sides of the furnace, for the admission of the blast to insure its equal distribution. The same idea is, of course, equally applicable to cupola furnaces, to which it has been applied by Mr. Ireland, of Manchester, in his "upper tuyere" furnace. That there is any real advantage in the upper tuyere furnace is still denied by some of those who have used it, and it is difficult to say wherefrom any substantial advantage should result. One of Mr. Ireland's cupolas, measuring 4 feet in diameter outside and 22 inches in diameter in the hearth or crucible, has three tuyeres of 6 inches diameter, and about 20 inches above these, eight tuyeres 2½ inches in diameter. A strong blast has much more influence than the subdivision or distribution of the blast, and we know that in blast furnaces enormous masses of ore, coke, and limestone, are penetrated by a blast of moderate pressure from but a few tuyeres arranged in a single row around the hearth In the United States a number of cupolas have been made of late years and used with considerable success, with an annular opening or port ¾ of an inch to 2 inches wide, around the whole inner circumference of the furnace, and with some of these furnaces with which I have had to do, their horizontal section was elliptical, measuring 9 feet by 3½ feet internally; and with a blast equal to 10½ inches of water, or ⅜-lb. per square inch, they brought down twelve tons of iron per hour. The full charge was 21 tons, which could always be brought down in two hours after turning on the blast, the annular tuyere or port being nearly 20 feet in length around the furnace, and 1¼ inch wide, although a large part of this great tuyere area of, say 2 square feet, is obstructed by the charge in the furnace itself. Had I had time to do so I should have been glad to have prepared diagrams of these cupolas from the working drawings in my possession. The elliptical section of furnace was adopted many years ago in cupolas in some of the German iron foundries, and it was revived in Alger's blast furnace, of which a good deal was heard in England about eight years ago. It cannot be asserted that it has any advantage, while it clearly has certain disadvanges in increased surface and cost of construction. The object sought in the elliptical furnace is that of containing a large charge with but a moderate distance between the opposite sides of the furnace, but here an increased pillar of blast will fully compensate for any increase of distance from the tuyere to the centre of the charge.

I have always believed that a decided advantage would result, in the case of cupolas, by having the drop bottom in general use abroad; I doubt if there are a dozen cupolas in America with the irremovable bottom as adopted in English practice. The severe labour in raking out the bottom of an ordinary cupola would be saved by the drop bottom, where the mere withdrawal of the bolt sends whatever is in the furnace into a pit below. The American cupolas are built upon a cast-iron base ring, which is supported upon three cast-iron columns, at a height of, say 2 feet above the foundry floor. This base ring is of the external diameter of the cupola, say 5 feet, and its internal diameter is that of the circular trap door, known as the drop bottom. The trap door will be, say 2 feet in diameter, 1½ inch thick, and having a coombing 4 inches high carried around its upper edge to receive a paving of fire-clay or a round fire-clay tile to support the charge. In my own practice I have hinged this door by a 1½-inch hinge bolt, 28 inches long, with a stout head at one end and a cotter in the other, the lugs or ears in the door and in the base ring were each 4 inches long, and of good thickness. The door was held up by a draw bolt, passing through staples of great strength in the base ring, the bolt being of 3 inches by 1½ inch iron. It is often said, "what if such a trap door should give way, with from three tons to ten tons of iron in the cupola?" Such accidents never happen, nor would they be attended with any great danger if they did happen. The iron might be lost, but that would be the worst of it. To shut the trap door a stout wrought-iron stalk descends from its centre for 18 inches, a heavy ball being fixed upon the end of this staple. A chain is attached to this ball, and the drop or trap can be thus easily moved by hand when the draw-bolt is out.

After the cupola an improvement is desirable in the blast apparatus. The rotary fan is in almost universal use in foundries. In order to obtain a pressure of 20 inches or 24 inches of water, with three square feet of tuyere opening, a 3-feet Lloyd's fan is usually driven at from 1500 to 1800 revolutions per minute, the tips of the vanes moving, say at the rate of nearly three miles per minute. From fifteen to eighteen horse-power are required, and with an old-fashioned fan much more. Besides the power there is to be considered the wear and tear of straps running at a high velocity. For considerable pressures of blast, to which foundry practice is tending, the direct compression of the air by a piston is more economical than the fan blast. For a blast furnace, of course, no form of fan would be practicable at even a pressure of 2½ lb. per square inch, still less at 5 lb. to 6 lb., as is occasionally employed. I have seen a steam blowing engine used with excellent results in a large foundry where the air cylinder was in a line with a steam cylinder, both the steam and the air pistons being fixed to the same rod, while a pair of connecting rods worked a fly-wheel to carry the engine over the centres. The same class of blowing engines, working at an air pressure of from 15 lb. to 20 lb. per square inch, is now employed by Mr. Bessemer in blowing air into his converters. For more moderate pressures, however, a rotating apparatus is preferable. In gasworks, where the difference of pressure in the retort and in the purifyers is, perhaps 1 lb. per square inch, it is usual, in the London works at least, to employ Beale's exhausters. No gas engineer would think of employing a fan for exhausting. Mr. Beale's exhauster is constructed somewhat upon the principle of a rotary pump, patented by the late Mr. Siebe, a father of the present Mr. Daniel Siebe, in 1828. This pump has been reproduced in the States as Cary's pump, and it was the water-pump adopted in the American steam fire-engine exhibited in the International Exhibition of 1862. An almost identical machine, for pumping air instead of water, is now in extensive use in American iron foundries, under the name of M'Kenzie's blower. Many of my friends who have used these blowers prefer them to fans, as taking less power, while they are of course capable of working at any pressure of blast required. One of those blowers, now at work in a locomotive factory of which I was engineer in 1854, is 26 inches in diameter, 3 ft. 6 in. long, and at a speed of 100 revolutions per minute, blows against a pressure of 21 inches of water in supplying a large cupola. The power required is found to be much less than that consumed by a fan, especially at high pressures, while the wear of straps is very moderate, the lineal rate of the driving strap being now about 300 feet instead of something like half a mile a minute, as with a fan.

I shall devote the further portion of the present paper to the consideration of—1. Means for increasing the strength and hardness of castings. 2. Means for insuring uniform cooling in castings after pouring. 3. The treatment for malleable castings. 4. Chilling.

At one time, when cast-iron was employed for boilers, shafting, large ordnance, and bridges, its strength was of great consequence. It has now become usual to employ wrought-iron or steel for the application just named, and, indeed, wherever great absolute strength is required. Even engine beams, since the lamentable failure at Hartley, are being made of wrought-iron. So the importance of great strength in castings has, no doubt, been lessened; and for most purposes it has been found cheaper to employ a somewhat larger quantity of ordinary iron than to pay a higher price and incur the delay often attending the search for a superior quality. For many purposes, indeed, as in engineers' tools, a liberal allowance of metal is requisite to secure stiffness; a kind of stiffness better provided in such cases by inertia, or mere dead weight, than by the absolute resistance of the metal per square inch. Yet there are still purposes, as in the case of railway chairs, water pipes, columns, &c., without mentioning hydraulic press cylinders and steam cylinders, where great strength in cast-iron is of much importance; and cast-iron is still the material principally employed in America for cannon of 13-inch, 15-inch, and, in recent instances, even 20-inch calibre. This is not the cast-iron however, of which guns have long been made in England, and were it not indeed greatly superior to our own, it would never withstand the proof and service charges which the heavy ordnance in question is known to bear. The report of the chief of ordnance in the United States navy gives the service of one of the 15-inch cast-iron guns as follows:—It was fired 900 rounds with a 440-lb. solid shot. The charge of powder, at first 35 lb., was successively increased to 50 lb., 60 lb., and 70 lb. With 60-lb. charges 220 rounds were fired, and the gun only burst with a 70-lb. charge and 440-lb. shot at the end of 900 rounds. It is doubtful if even as good results have been, or will be, attained by the most carefully made wrought-iron guns of the same calibre. Upwards of 100 of these 15-inch guns are now in service. Before going on with the consideration of how such great strength in cast-iron is attained, it may be as well to give the following notes of the 20-inch cast-iron guns, of which a number have already been made. They weigh 51½ tons each, and the first of these guns was thirteen days in cooling. They are 20 ft. 3½ in. long over all, and 17 ft. 6 in. long in the bore. Their greatest diameter is 5 ft. 4 in. They are fired with 100 lb. charges of powder, and a solid shot weighing 1000 lb.

I shall say nothing of the selection of particular brands of iron, nor of the great importance of proper mixing in the cupola, for I could only say, what every qualified founder well knows, that upon these a great deal depends. I could give no directions better than those upon which founders now act, each having to choose and mix the irons which he has found best for his own purposes in his own district, for it is always important to him not to send further than is necessary for his pigs. But there are modes of increasing the strength of a large number, if not all, of the irons known to commerce, and although there is still much doubt as to the relations between the chemical constitution and the strength of iron, it is certain that all the known modes of strengthening cast-iron are modes whereby its proportion of uncombined carbon and of silicium is known to be diminished. If we puddle cast-iron up to a certain extent, and stop at the right point, we have steel of very great strength, and if we carry the puddling far enough we have wrought-iron. So if we melt cast-iron with wrought-iron, as in making what is called Stirling's toughened metal, we lessen the relative proportions of the impurities to the iron as contained in the pig, and if we do not get a remarkably tough metal, we, at any rate, produce one of great hardness, and some of our locomotive makers employ such a mixture purposely to obtain hardness in their steam cylinders. So also, by oxidizing cast-iron at a high heat, as in the treatment for malleable iron castings, we gain undoubted strength and toughness. Here too, the carbon and silicium of the iron are lessened in quantity, and so it may be apprehended that they are by the American practice of re-melting all the iron employed for cannon and keeping it for some time in fusion. This practice at one time went so far as three and even four re-meltings, the iron being kept in the fluid state for three hours at each melting. In this way the tensile strength of iron, ranging from 5 tons to 6½ tons in the pig, has become 9 tons at the first casting, and after remaining in the melted state for two hours, 13 tons at the second casting, and 15½ tons per square inch at the third casting, the period of fusion at each melting being from one to three hours. The final strengths thus reached are very great in one case, reported by Major Wade; of the United States Ordnance Board, a tensile strength of 20½ tons per square inch of cast-iron having been obtained. The American ton is generally 2000 lb., but the strengths I have quoted are in tons of 2240 lb. These great tensile strengths do not appear however to give a tough metal, using the term tough to express the product of the cohesion and extensibility of the iron. It was found that, in employing iron having an average tensile strength of 38,000 lb., or 17 tons per square inch for 8-inch guns. they burst at the 70th or 80th fire, while 10-inch guns made from iron having a strength of 37,000 lb. per square inch, burst at the 20th round. This was known in 1851, and in the following year, at the Tredegar Ironworks at Richmond, Virginia, where I was then engaged, and which was one of the leading foundries for supplying cannon to the United States Government, a return was made to iron of a strength of 30,000 lb., which having more elasticity, as it was then thought, gave a really stronger gun. It has since been ascertained that the real fault with the stronger iron was that it contracted more in cooling, and as insufficient provision was made for equal contraction throughout the casting, the guns of strong iron were thus under great initial strain from their own shrinkage. This very strong gun iron contracts generally three-sixteenths of an inch per foot in casting. The driving wheels of American locomotives are of cast-iron, and when in 1851, to secure greater strength against breakage, gun iron of a strong quality was experimentally used, it was found that the wheels broke worse than ever, as they were strained to a great extent by their own shrinkage before they came out of the foundry. This gun iron is simply the better classes of iron mixed and melted in an air furnace, the cupola never being used for guns, as indeed it never ought to be used for any castings intended to have great strength, on account of the over-heating of portions of the metal and the direct action of whatever sulphur may be contained in the coke. In the Bessemer process, where the exclusion of sulphur is so important, the pig metal is for this reason melted in a reverberatory furnace, or air furnace, as it is sometimes called.

Now, as all the processes whereby cast-iron is strengthened are processes whereby its proportion of contained carbon and silicium is diminished, some quicker and much cheaper mode of effecting this object is required than that by re-melting or by partial puddling. This quicker and cheaper mode would be had by a partial application of Mr. Bessemer's treatment, that is by blowing air through the iron for perhaps three or four or five minutes, instead of twenty. But, it will be asked, if you are to have the Bessemer apparatus at all, why not convert the iron at once into steel? There are several reasons why we should not. To make steel, a much higher quality of iron, and generally the addition of spiegeleisen, is necessary. As steel the metal cannot be run into goods, but only into an ingot, which requires very heavy hammers to forge it, as well as machine tools of unusual strength to finish it after forging; the wear of the converter and other plant would be much greater for steel than for toughened iron. The waste of metal before the finished article, whatever it might be, could be produced, would be greater for steel than cast-iron. I have recommended this partial application of the Bessemer process, and I believe that when more attention comes to be given to strength in castings, this treatment will be adopted. The apparatus for carrying it out would be exceedingly simple, and would be worked with but little trouble, a blast being derived from the rotary blower already described.

But absolute strength in the iron of large castings is of little consequence unless they cool, after pouring, in such a manner as not to leave them subject to considerable internal strains. We know that the late Professor Hodgkinson found that with the iron he experimented upon the compressive strength was six times that in tension, and hence that the bottom flange of a cast-iron girder should have six times the sectional area of the top flange. But very few, if any engineers adopt such a proportion, as the casting would, in all probability, crack in cooling. Most of my audience have seen the cast-iron bridge over which the London and North-Western Railway crosses the Regent's Canal. The first girders for this bridge were cast at the Tinsley Park Works. The iron made there was very hard; and I have been told by my friend, Mr. Shanks, who was engaged there at the time, that it would chill to a depth of 2 inches. It was used, among other things, for making rollers to roll steel. The Regent's-canal bridge drawing was sent down there, and they made the patterns and cast the girders. They broke through and through in cooling. Then they altered the patterns; and by pulling off the sand from the thicker portions of the castings, so as to equalise the cooling, a number were cast with the loss of one out of every six. At last, six were sent up to London; and of these every one broke in a thunder storm. Other girders were then cast of different form. Castings, overstrained in cooling, are apt to break under even a moderate degree of vibration; and the late Mr. Rastrick, once of the Bridgenorth Foundry, and afterwards engineer-in-chief of the London and Brighton Railway, once stated in evidence how a number of cast-iron boilers he had made cracked open after a peal of thunder.

I have seen, and so, no doubt, have many others, a railway wheel cast in a chill, and which, on being taken from the mould immediately after pouring, broke in two within a quarter of an hour. And, if the experiment were made, there is not the least doubt that a heavy gun, pulled out of the sand as soon as the metal had set, and then finished, would burst at the first round. The outside would cool first, compressing the liquid iron within. This, cooling afterwards, would pull away from the iron already set around it—or, if it did not actually separate, the strain of contraction would be such that the gun would be ready to crack as soon as it was violently disturbed. An unannealed glass tumbler is as good a comparison as any. The old-fashioned playthings, Prince Rupert's drops, illustrate the same effect of internal strain due to unequal cooling, glass being particularly brittle in this respect, in consequence of its low conducting power, and from its having no ductility when cold.

To make a casting of great strength it is necessary that all parts cool alike or nearly so. In the case of guns cast solid the core bored out is often found honeycombed by retarded cooling; and the metal forming the surface of the bore can be proved to be under considerable initial strain in consequence. Of course guns were cast hollow many years ago; but not until 1847 was it proposed to cool the core, after casting, by means of water circulating in pipes within it. Captain Rodman, in that year, patented the mode by which all the larger American guns have been cast. Within the core are two water pipes, one inside the other, and like those in Mr. Field's boiler, known to so many in this society. Water flows down the inner pipe, which is open at both ends, and rises through the outer pipe, which is closed at the bottom. A perfect circulation of water is thus secured. In casting one of the 20-inch guns, February 11th, 1864, water was thus run through the core for twenty-six hours, at the rate of thirty American gallons per minute for the first hour, and sixty gallons per minute for each subsequent hour, equal to 341 tons of water in all. The iron was considered of too hard a quality to be further cooled by water, and for the next twelve days air was forced down the bore of the gun at the rate of 2000 cubic feet per minute. During the first hour after casting the water flowing in at 36° came out at 92°. During the second hour, with twice the quantity of water flowing through, it came out at 61°. In other cases, in casting 10-inch guns, as much as 700 tons of water have been run through the core, the water-cooling occupying four days, or nearly 100 hours. In some of these cases, a fire was made at the bottom of the gun-pit, and continued for sixty hours, the outer iron casing of the gun mould being kept at nearly a red heat for the whole time. It is by these means that all parts of the gun are cooled alike, or nearly so, and, with iron of a tensile strength of, say 13 tons per square inch, that such great endurance has been attained in firing.

Nearly all the railway wheels in use on the American lines are of cast-iron, chilled on the periphery, It is not merely that these wheels are cheap, but they are preferred to the wrought-iron wheels as used on English railways. I am not now speaking of the engine driving wheels, but of the carriage and waggon wheels, of from 2 ft. 6 in. to 3 ft. in diameter, although the size is very seldom greater than 2 ft. 9 in. The cast-iron wheels run until they are worn out, and they wear for a long time; whereas the wrought-iron wheels require frequent turning, and still worse, their flanges soon become worn so thin as to become unsafe, a fact due, perhaps, to the inferior condition of the American lines. It was, however, a long time before the American founders could produce chilled wheels which should be safe under all circumstances; and when it is remembered that they are now employed as the leading wheels of the heaviest express engines working on lines, of which, what we should call the ballast, is sometimes frozen as hard as a rock for two or three months in the year, and in a climate where the mercury is occasionally from 10° to 20° below zero, or 40° to 50° of frost, and when it is added that these wheels do not break oftener than wrought-iron wheels on the best English lines, it must be added that they are as safe as anything can be. In this I am speaking from my own knowledge, extending over a period of ten years, during the whole of which time I was closely connected with the leading American locomotive factories and lines of railway. The founders had to obtain not merely strong iron, in respect of tensile strength, but an iron of considerable toughness, and besides, an iron that would chill well. As a rule, such iron is only obtained by careful mixing; and it must be sought by long and costly experiment. I do not doubt that iron for excellent chilled wheels, if they were ever required, might be found in England; but I would not run the risk of saying what mixtures would produce it, although I should say Blaenavon cold blast and the Forest of Dean irons would enter into such a mixture, with a little iron like that made at Tinsley Park for hardening. The chief difficulty with the American founders was that presented by the unequal contraction of the wheels in cooling. At first the wheels were made with spokes, but as the rim was quickly cooled in the chill, thus compressing the still fluid iron in the nave, which subsequently contracted away from the rim, it was necessary to divide the nave radially into two or more portions, and to afterwards fill the openings thus made in the nave with lead and antimony, a pair of stout wrought-iron rings being shrunk over the ends of the nave, to compress it properly upon the axle. But it happens in the case of spoke wheels cast in a chill that, from the greater quantity of iron at the ends of the spokes, the chill is softest there, so that the tread of the wheel wears into as many flat spots as there are spokes. This is one of several reasons why the disc form is to be preferred for chilled wheels, but there was the difficulty of providing against their unequal cooling. The disc being whole or undivided, the nave had to be left whole also; and so, unless the disc could yield laterally during cooling, or unless the whole wheel was cooled uniformly, a great strain would result in the disc and rim. So the discs were dished, or curved in cross section; indeed, the variety of form to be found in the earlier chilled wheels of the disc pattern was something remarkable. At last, one of the leading founders, Mr. Whitney, determined to try the effect of equal cooling. He cast his wheels solid, as the others had done, but with a single and perfectly flat disc, stiffened by straight or radial ribs at the back. Such a wheel, pulled out of the flask when red-hot, and thrown out to cool in the open air, would crack open in a few minutes. Mr. Whitney, however, took his wheels from the flasks as soon as the iron had set, and lowered them at once by machinery into a deep pit made in brickwork, and which had previously been heated as hot as the wheel itself. The pit being filled with wheels placed one over the other, and separated by iron rings, was closed air-tight, and left with its contents to cool. The cooling occupies three days; and it is therefore so much slower than the progressive conduction of the heat from one part of the wheel to another, that all parts must cool absolutely alike. The result is that the wheels thus annealed may be so nearly cut open, by a turning tool in a lathe, as to leave but a thin film of iron connecting the boss and the rim, and yet, until struck with a hammer, the nearly separated portions do not come apart. The chill appears to take place at the moment when the melted iron meets the iron mould; and the heat of the annealing kilns does not affect the hardness of the chill in the least degree. Mr. Whitney's wheel factory in Philadelphia is the largest and best fitted in America; and his wheels, made and cooled as just described, are in use throughout the States; and are preferred to all others, even to the best English made wrought-iron wheels, a number of which, by the Lowmoor Company, were put in use on the Hudson River Railroad in 1851, where the flanges of the tyres soon came to be cut so thin under the constant wriggling of the bogies or truck frames, that they had to be soon replaced with chilled wheels. Although we are considering the improvement of castings generally, I have dwelt at some length upon these wheels, because, from their severe service and the improvements made upon them, they illustrate in a convincing manner, the importance of equal cooling. I wish it to be quite understood that I refer to chilled wheels only as an illustration, and however well they answer their purpose in America, I am not recommending their adoption here. But I am certainly of opinion that, in the case of many castings, especially those of irregular form and those of great size, their strength would be doubled were they properly cooled; and it is more from the want of precautions in cooling than from any inherent untrustworthiness in cast-iron itself, that it has come to be regarded with doubt for purposes requiring great strength.

The next point to be considered is the treatment for making castings malleable. I should have said nothing of this were it not that, although exceedingly simple, it is but very little understood, for it is a very common notion that many and curious "chemicals" are required, and that there is much mystery in the process. Making iron castings malleable was indeed among the lost arts, and old records show that it was lost and rediscovered more than once. The French philosopher Reaumur, who wrote upon it 140 years ago, observed that it was then practised as a great mystery in Paris. At last chemistry came to the aid of the metal worker, and he learned that what he had so long called sulphur in the iron—and sulphur was once a name applied to many substances—was really carbon, the same as charcoal or diamond. And chemistry showed how carbon would always forsake iron for oxygen, and that cast-iron, treated with oxygen, was made malleable, as it always is, whether in the old refinery fire, in puddling, in pig boiling with forge scales and refinery cinder, in the Bessemer process, and in still other modes of treatment. In 1804, Samuel Lucas, of Sheffield, turned this knowledge practically to account. He took out his patent, too, and described his improvement very cleverly; and, to put it in the fewest words, it was nothing more than the present process of making castings malleable by roasting them, at a high heat, for from 72 to 120 hours in powdered hematite iron ore, or in any metallic oxide. The oxygen of the ore unites with the carbon in the iron casting, which, being thus left without carbon, becomes malleable—malleable, indeed, to a remarkable degree. It is commonly said that castings intended to be malleableised should be from very hard, brittle iron. It is not exactly because a casting is brittle that it is of the best sort for the malleable iron treatment, but brittle castings contain less carbon than those from grey iron, and so the malleable process does not have to be so long continued to get rid of it. To those who are not accustomed to consider all forms of iron and steel as combinations merely of iron and carbon in different proportions, there is something a little paradoxical in the fact that a grey iron containing much carbon is tough; a white iron, containing less carbon, is brittle; steel, containing still less carbon, is also brittle; while wrought-iron, containing but little carbon, is very tough. Even to a chemist these facts are not easy to be explained; nor shall I examine them further here, it being sufficient merely to have shown why a white and brittle cast-iron, such as some of the Ulverston iron of which clock bells are made, is the best for the malleable iron process, because it contains less carbon than a grey iron. The castings must be packed perfectly air-tight in layers of powdered ore, and shut up in cast-iron boxes, of which the joints should be luted. The natural ore used for purifying gas at the various stations of the Chartered gas works would, no doubt, answer very well for malleable castings, although it cannot be said whether Mr. Hill's oxide would do as well. The goods should be heated very gradually, twenty-four hours being ocupied in getting up, and twenty-four hours more in letting down the heat, besides the two or three days at full heat. The heat should be very even over all parts of the goods, and while the full heat is on it should be kept constant by careful firing and attention to the draught. The iron ore may possibly fuse upon the surface of the casting, thus covering it with lumps or warts; but this is the result of too high a heat, or of access of air. Oxide of zinc, which is abundant in some parts of America—as near New York—is preferable to iron ore, but those who cannot obtain the former can get on very well with the latter. The agricultural implement makers have turned the properties of malleable cast-iron to good account for the tines of their cultivators. At the large works of the Messrs. Howard, of Bedford, unusually large pieces are made malleable by roasting in hematite ore. McHaffie's malleable castings made in Glasgow—and for which it is generally supposed that there is a patent, although I believe there is none—are no doubt made in much the manner described, as also, no doubt, are Crowley's of Sheffield, although different makers add various chemical substances, which may act in the same manner as the iron ore, and thus, to a certain extent, replace it, although it is doubtful if they greatly promote its real action. Wherever a shape can be easily made in wrought-iron, this is probably cheaper than a malleable casting, and it is doubtful, therefore, whether the latter will ever be extensively used. It may be added that the tensile streugth of malleable castings varies according to their size, and the depth to which the decarburisation extends. If they were freed of their carbon all the way through, they would be converted into wrought-iron, or, say "homogeneous metal," as the softest kind of steel has been called. So much of the casting, however, as is not decarbonised by the malleable iron treatment, remains cast-iron, and has only the strength of cast-iron. The effect of the process is generally visible for only a small depth below the surface, but small malleable iron castings have borne a tensile strain of 50,000 lb. per square inch.

On the last point named in the earlier portion of this paper—

the production of chilled castings—there is not very much to be said. It is for the founder to ascertain, from his practice and from such experiments as he is in the best position to make, which irons will chill and which will not. Of those that will chill, it is important, if the chilled casting have to be put under great strain, that the chill be well blended with the softer iron, instead of there being a distinct line of demarcation. It may be that the best application for chilled castings will be that for chilled shot, which, at far less cost, come nearest to steel. To cast shot in chills, with the best results, it may be found best to subject the iron, just after pouring, to a considerable steam pressure. By simple mechanical arrangements easily devised, a pressure of 100 lb. of steam per square inch, equal to a column of iron upwards of 30 feet high, could be turned instantly upon a casting just poured into a chill mould. The effect would be to secure greater density and uniformity in the casting, and to render it stronger for its purpose. It is well known that "head," or a high rising column of metal over the mould, is an important matter in making strong castings, and that, in some cases, as in casting sugar-mill rolls, this head or "gate" of metal is well churned by manual labour. There can be no doubt that steam pressure would answer the purpose still better, nor that the best mode of applying this pressure might be easily determined.

The very cheapest applications of iron are in its condition of cast-iron. For some purposes, as for heavy ordnance, it is questionable whether cast-iron is not really equal to wrought-iron and steel. It is certain that comparatively little has been done in this country to improve the strength of large castings, and that, in some cases, wrought-iron has been adopted, without sufficient attempts to meet the requirement with a much cheaper and more adaptable material. It cannot be argued that, in arched bridges, like some of those now erected and in course of erection over the Thames, wrought-iron is equal to cast-iron in its resistance to compression. It is probable that absolutely better and cheaper structures could be put up in cast-iron. It is to be hoped that the careless practices which formerly prevailed of casting large pieces on the foundry floor, and of paying little attention to uniform cooling, have not permanently deprived us of one of the best applications of one of the most important materials of construction.

CREEDS AND TEMPLES: THEIR RELATION TO ONE ANOTHER, IN PAST AND PRESENT TIMES.

By H. H. Statham, Jun.

In considering some of the relations between different religious creeds and the buildings to which they gave rise, I do not of course mean to go into a detailed history of temples and rituals. But it may be worth while to take a glance, successively, at the religions which have left the most remarkable architectural monuments of their existence (considering them, of course, from a purely speculative, not from a theological point of view), and to observe how the requirements or spirit of the religion were represented in the plan or style of the building; not merely for the interest of the subject, but in order also to obtain standing ground from whence to view our own position, and to consider what are the legitimate demands of Christian worship upon architecture in the present century.

Modern ethnologists, it is well known, have divided mankind into three great families, generally known as the Aryan or Indo-Germanic, the Semitic, and the Turanian or Tartar races, emerging successively from the same quarter of the globe, the region about the Euphrates, and the north-west of India; the Turanians being the earliest developed, the Aryans the latest and most intellectual; and in early historic times each of these races had its own peculiar class of religious belief, the influence of which may be traced even to the present day. What may be called the Theistic faith, recognising the existence of an omnipresent yet personal deity, was the peculiar property of the Semitic race, represented by the Jews, and in later times by the Arabians. The primitive Aryans, the earliest representatives of whom are the ancient Persians or Magi, were the high priests of Pantheism, or the worship of external nature; while among the ancient Egyptians, the earliest Turanian people we are acquainted with, we find ourselves in the midst of the wildest and most fanciful Polytheism. And here we at once notice a remarkable fact, of which we find additional evidence in later times, that it is to the various forms of Polytheism that we are indebted for the grandest and most impressive sacred buildings. The Jews, as we know, were not required by their religion to erect more than one temple; and even that, though richly adorned, was always too small in dimensions to be taken into any account by the side of such piles as Karnac and Luxor, Cologne and Amiens; while to the early Persians, holding a faith in which the elements were the ministers, and the sun the chief object of worship, a temple could only have been an incumbrance. The extraordinary contrast between the Aryan and Turanian races in these points, is very well put before us in the words of an eminent ethnologist, Dr. Pritchard, who remarks that "the metaphysical belief and religious sentiments and practices of the two nations were equally diverse; the one adoring an invisible and eternal spirit, at whose word the universe started into existence, and the morning stars sang together; the other," the Turanian, "adorning splendid temples with costly magnificence, in which, with mysterious and grotesque rites, they paid a strange and portentous worship to some foul and grovelling object—a snake, a tortoise, a crocodile, or an ape." It is, then, to the banks of the Nile, under the influence of such a worship as this, that we turn to find the first development of ecclesiastical architecture.

Sir Gardner Wilkinson considers the germ of the Egyptian temple to have been a simple cella, with a porch, which always remained of nearly the same size and form, though in process of time surrounded with one adjunct after another, till it assumed the form represented in the plan of the temple of Rhamses the Great, which is a pretty fair type of the great Theban temples. The whole arrangement of these temples is clearly indicative both of the mysterious and superstitious character of the worship for which they were erected, and of the splendour of the ceremonial by which a powerful priesthood sought to invest the religion with dignity and solemnity in the eyes of the common people. And it may here be remarked that, both in this and in all subsequent temple styles, the extent and magnificence of the plan are in almost direct proportion to the power and influence of the priesthood. In ancient Egypt the priestly caste was predominant over every other, and never, certainly, has there been a more successful attempt to give an outward sublimity to a worship essentially contemptible than in these temples of the Theban dynasty. The long avenues of sphinxes, sometimes stretching for nearly a mile from the gateway; the entrance, with its great propylons towering on each side, and leading into a wide court-yard surrounded by the deep shadow of a covered colonnade; the second court, with its rows of seated colossi; the hypostyle hall of assembly, with its forest of columns, dimly lighted from above,—all these must have combined to produce an effect scarcely equalled since, and well calculated to suggest how awful must be the sanctity of those three dark cells to which all this grandeur formed only a vestibule. Into that sanctity, however, the people were wisely never permitted to examine, the king alone being occasionally introduced, a priest leading him by the hand, into the presence of the deity (a ceremony frequently represented in the Egyptian paintings), the mass of the people always remaining without, and participating in the sacrifice only through their priestly vicars. The triple arrangement of cells which seems to have generally prevailed resulted from the belief in a triad of deities presiding over each of the principal cities, and generally supposed to consist of a god, a goddess, and their son or daughter; and this belief (which is also to be traced among the Etruscans and Pelasgi) gave rise to the small temples called mammeisi, so remarkably resembling the Greek temples in plan, and which appear to have been considered as the nuptial halls of the deities. The most important ceremonials next to the sacrifices were the processions of the deities, who were occasionally borne in state, under a canopy, either round the courts of the temple or outside its enclosure; and we can easily imagine how important a part the avenues of sphinxes must have played in these probably gorgeous processions, and may perhaps trace to them the origin of the covered colonnade in the first court, as a provision for the spectators of the procession within the boundaries of the temple.

Altogether, the Egyptian temple may be viewed as the most complete outward expression of a religion in which the idea of the beautiful was almost entirely subordinate to that of the religious expression; no high order of æsthetic beauty being observable in the details of the building, even the lotus capital owing its prominent position as much to the sacred character of the flower as to its outward beauty; the statues deriving their importance less from their artistic merits than from their significance as representations of Osiris: every part of the building being constructed to subserve the purpose of enhancing the ideas of mystery which pervade the whole of the Egyptian mythology—the whole representing, indeed, the apotheosis of superstition, in the awful and imposing forms into which it had been, as it were, consolidated, during the lapse of centuries, by a people eminently conservative, and moving very slowly down the stream of history.

Breaking for a moment the chronological order of styles, and turning to Hindustan, the temple style of which arose as that of Egypt became extinct, we see the same phenomenon presented of the rise of temple architecture coinciding with that of priestcraft and superstition. For the earlier Sanscrit writings, the Vedes, which contain the original precepts of Hinduism, and which were long anterior to the rise of Hindu architecture, are essentially Pantheistic, and are said to show symptoms of derivation from the ancient Persians, having been, most probably, introduced into India by the portion of the Aryan tribe who penetrated there.

Long before this introduction, however, India was already occupied by a people of Turanian origin, and nearly connected with the Egyptians; and under the influence of these, as they advanced in civilization, the pure faith became gradually corrupted; the priesthood became a caste, continually increasing in power, and the original pantheism merged into a polytheism far more gross and degrading than that of the Egyptians. Hence was developed a form of temple which, as it arose under similar circumstances as did those of Egypt, so it bore to the latter a striking resemblance in several points. We find the same dignity given to the entrances by pyramidal gate-towers; the same pillared courts within courts; the same extraordinary bathos in plan, by which a whole array of entrance-gates, court-yards, columns, &c., presenting a gorgeous and striking exterior, but becoming smaller and meaner as they are penetrated, culminate at length (if one may use the word) in the one little insignificant chamber, lighted only through the door, and additionally darkened by a covered porch, which was perhaps the fittest kind of shrine for such deities as have been conjured up by the Hindus. Such a plan as this could only have originated from a religion in which a priestly caste stood completely between the people and the deity, and in which the imaginary deity partook not of the higher nature, but of all the baser and more degrading passions of humanity.

Going back in our chronology, and starting again from Egypt, we cross over to Greece, and here we are at once in a purer atmosphere, for we have got quit of the exclusive influence of the Turanian race. The ancient Pelasgi, indeed, the earliest known inhabitants of Greece, were of Turanian origin; but the Greeks, *par excellence*, were the offspring of the union between these aboriginal inhabitants and the great Aryan race, represented by the Dorian colonists, who joined their high intellectual power and common sense to the brilliant artistic capabilities of the Pelasgi. Hence their religion, though a polytheism, was of a bright and beautiful kind, being in fact a deification of the various attributes of nature, closely allied to the pure Aryan pantheism, and possessing few elements of mystery or superstition. No caste of priests here combined to blind and stultify the worshippers; the priests were the officers of the temple merely; the sacrifices and the worship of the deity were witnessed and joined in by the people. Accordingly we find here no labyrinths of courts within courts, no solemn vistas of statues, none of that expression of gloomy grandeur which we met with on the banks of the Nile; all that was required on plan was a simple rectangular chamber with the statue and altar of the deity at the further end of it, where sacrifices could be witnessed by all assembled in the temple. These peristylar temples seem to have been developed from a simple cella, in much the same manner as the Egyptian; though whether the original form came from Pelasgic or Egyptian sources appears to be a vexed question. The one exception to the simple character of the Greek form of worship is the celebration of the Eleusinian mysteries, which, however, are known to have been borrowed directly from the Egyptians, and which, as we might have expected, gave rise to a special plan of temple at Eleusis: a nearly square building, with columns equally spaced over the greater part of the area, and this plan, so different in proportion and arrangement from the ordinary Greek temple, has been supposed, I think with great probability, to have been suggested by the hypostyle halls of the Egyptians.

It seems probable, from various passages in later Greek and Roman writers, that these mysteries consisted mainly in scenic representations of the most significant passages in the Greek mythology, particularly in relation to a future state. In such a case it is easy to see that a plan like this, with the view partially intercepted in every direction by columns, and lighted from above by windows which could be darkened at pleasure, might greatly aid the effect of such exhibitions.

We know how amply the Greek temples compensated for their comparatively small size by the exquisitely artistic and finished character of their decorations, and in this way they present a remarkable contrast to the Egyptian temples, in two points not unconnected with the opposite character of the two religions. The first is, that the Greek ornamentation did not, like the Egyptian, owe its interest to its sacred or symbolic meaning; of this it possessed nothing, for the Greeks were far too intellectual to descend to material symbolism; all their decoration was placed there solely for its artistic effect, and if, as before said, the Egyptian style was the apotheosis of superstition, the Greek was certainly that of æsthetic beauty. Secondly, the phonetic art introduced into the Egyptian temples, the endless wall-paintings of nearly every possible subject, had no relation to any previously compiled and well-known histories of things, either sacred or profane: they were themselves the book; and, like the painted windows and sculptures of the Mediæval cathedrals, were probably the chief sources of instruction to the mass of the people. The Greek sculptures, on the other hand, were only the illustrations of the most beautiful Pagan mythology, and the most splendid literature, Pagan or Christian, that ever existed; the heroes and gods of Homer lived again in the friezes and tympana of the temples:—

> "Nor these alone, but every legend fair,
> Which the supreme Caucasian mind
> Carved out of nature for itself, was there,
> Not less than life, design'd."

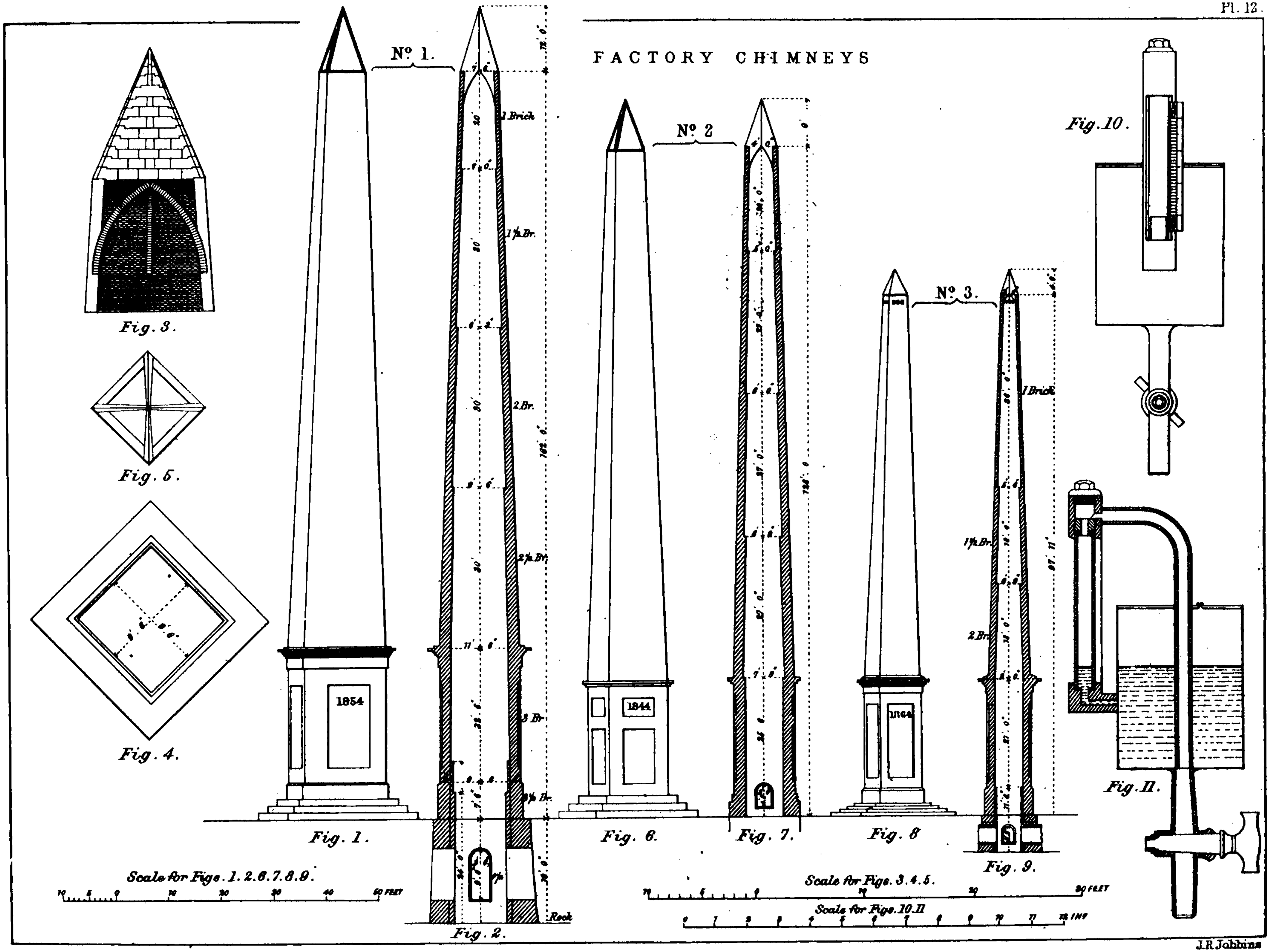
The Romans contributed but little to the temple-styles of the world; they were an Aryan race, displaying in excess the matter-of-fact character and comparative indifference to religious art which has always belonged to this division of the human family. Their temples and religious rites were chiefly borrowed from the Greeks, as those of the Greeks in many cases from the Egyptians; but while the latter merely borrowed, and vastly improved on their models, the Romans started with copying, and soon spoiled and vulgarised all the details in the process. One form of temple, however, possesses an interest for us, as being the model on which the Christian baptisteries were afterwards built; I refer to the circular form, which was borrowed from the Etruscans, a Turanian race nearly allied to the Pelasgi, and holding the same place in ancient Italy as the latter in ancient Greece; with this distinction, that the Roman colonists did not, like the Dorian, fuse themselves with this aboriginal race, but overpowered and superseded it. Originally these circular buildings were probably tombs, for the Etruscans were essentially a tomb-building race, owing to the reverence in which they held their ancestors; and though the Romans used them as temples (always dedicating them, however, to deities of an Etruscan and not of a Roman origin), the traditional use of them showed itself again in the Christian era, in such buildings as the tomb of Theodoric and the circular church erected by Charlemagne at Aix, to form his own sepulchre; and even in the Christian baptisteries the same feeling may be traced, inasmuch as these buildings were commonly erected over spots consecrated by the entombment or martyrdom of a saint.

(To be continued.)

INSTITUTION OF CIVIL ENGINEERS.

April 11.—The paper read was on "*The Festiniog Railway for Passengers—as a 2-feet gauge, with sharp curves, and worked by locomotive engines*," by Captain H. W. Tyler, R.E., Assoc. Inst. C. E.

This line was designed to facilitate communication between the principal slate and other quarries in the county of Merioneth and the shipping places, and for the conveyance of coals and other heavy articles to the quarries and mines. As in 1832, when the act for its construction was obtained, the population was very limited, the line was laid out in an economical manner, with a width between the rails of 2 feet only. It commenced at Portmadoc, and after passing along the Traeth Mawr embankment, it ascended to the mountain terminus at Dinas, the level of which was 700 feet above the station at Portmadoc, by an average


FACTORY CHIMNEYS
No. 1.
No. 2
No. 3.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8
Fig. 9.
Fig. 10.
Fig. II.
1854
1844
1 Brick
1½ Br.
2 Br.
2½ Br.
3 Br.
Rock
Scale for Figs. 1. 2. 6. 7. 8. 9.
Scale for Figs. 3. 4. 5.
Scale for Figs. 10. II
J. R. Jobbins

gradient of 1 in 92, for 12½ miles, the total length of the line being 13 miles. The steepest gradient on the portion now used for passengers was 1 in 79·82, and on that traversed by locomotive engines 1 in 60. Some of the curves had radii of 2, 3, and 4 chains. The maximum super-elevation of the outer rail on 2-chain curves was 2¼ inches for a speed of 8 miles an hour. The estimated cost of the line was £24,185, but the parliamentary capital was raised to £50,185.

The quarries being situated at different altitudes in the mountains, the slates were first brought down the quarry inclines to the railway, and the trucks were collected until fifty or sixty had accumulated to form a train, which was then allowed to run down by gravity. Until the year 1863, the empty trucks, or those loaded with coals, goods, furniture, materials, machinery, and tools for the quarries and the neighbourhood, were drawn up by horses, who travelled down with the trains, as on mineral or colliery lines in the North of England. As the traffic increased, the line was gradually improved, by flattening the curves, by making better gradients, and by improvements in the permanent way, and as the trade still continued to progress, the practicability of employing locomotives was constantly discussed. The apparent difficulties caused the idea to be more than once abandoned, but ultimately, in June 1863, two locomotive engines, designed by Mr. England, under the direction of Mr. C. E. Spooner, the engineer to the company, were placed upon the line, and having been found to be successful, two others were subsequently supplied. These four engines had run 57,000 miles up to February 1865, without leaving the rails. During the last autumn, the company carried passengers without taking fares, but at the commencement of the present year the line was regularly opened for passenger traffic. In ascending from Portmadoc, the passenger carriages were drawn by the engines with other vehicles, the passenger carriages being placed between the empty slate trucks, which were always last in the trains, and the goods waggons, which were next behind the tender. In descending, the loaded slate trucks, with empty goods trucks attached behind them, ran first in a train by themselves, the engine followed, tender first, and the passenger vehicles brought up the rear, with a break in front, but detached from the engine and tender, and at a little distance behind them. The speed was limited to about 6 miles an hour in passing round the sharpest curve, and to 10 miles an hour on other parts of the line.

The engines were somewhat similar to, though much smaller than, those which had been found so useful to contractors. There were two pairs of wheels, coupled together, and 5 feet apart from centre to centre, the wheels being each 2 feet in diameter. The cylinders, which were outside the framing, were 8 inches in diameter, with a length of stroke of 12 inches, and they were only 6 inches above the rails. The maximum working pressure of the steam was 200 lb. to the square inch. Water was carried in tanks surrounding the boilers, and coal in small four-wheeled tenders. The heaviest of these engines weighed 7½ tons in working order, and they cost £900 each. They could take up, at 10 miles an hour, about 50 tons, including the weight of the carriages and trucks, but exclusive of that of the engine and tender. They actually conveyed daily, on the up journey, an average of 50 tons of goods and 100 passengers, besides parcels. Two hundred and sixty tons of slates were taken down to Portmadoc daily. The engines were well adapted for convenience in starting and in working at slow speeds; but their short wheel base, and the weight overhanging the trailing wheels, gave them more or less of a jumping motion when running. Safety guards, similar in form to snow ploughs, had been added in front of the engines, behind the tenders, and under the platforms of the break-vans, in consequence of their being so near to the rails.

The passenger carriages were 6 ft. 6 in. high in the middle above the rails, 10 feet long, and 6 ft. 3 in. wide, they were on four wheels 18 inches in diameter, and 4 feet apart from centre to centre of the axles. There was a longitudinal partition down the centre, and the passengers were seated back to back, so as to avoid overhanging weight outside the rails. The second and third, costing £100 each, did not differ from the first class carriages (which cost £120 each) except in their fittings. Each carriage would convey ten passengers. The floors of the carriages being only 9 inches above the rails, no platforms were required; and there being no break in the longitudinal partitions, the passengers got in and out through doors on both sides. There were also some open cars for summer use, without sides or roof, into which the passengers were strapped by means of longitudinal and cross straps. The couplings were central, 15 inches above the rails, and working upon volute springs. The buffers were also central, and were 4½ inches above the couplings.

The rails weighed 30 lb. to the lineal yard, and were supported in cast-iron chairs, weighing 13 lb. at the joints, and 10 lb. each in the intermediate spaces, placed upon transverse sleepers of larch. In transforming this horse-tramway, thirty-three years old, into a passenger line worked by locomotives, the narrowness of the works, among other things, caused some difficulty. The author thought that in all new lines a minimum distance of 2 ft. 6 in. should be preserved between the sides of the carriages and the works, and that where there were two lines of way, an intermediate space of 7 feet should be allowed, to admit of the doors of the carriages in one train swinging clear of those of another train.

The author conceived that the employment of locomotive engines on this little railway, and its opening for passenger traffic, were not only highly interesting experiments, but were likely to be followed by important results. Although there were still doubtless, numerous districts where railways on a gauge of 4 ft. 8½ in., might be profitably made, yet there were also many others in which lines of cheaper construction were required. With a narrower gauge, lighter rails and sleepers, less ballast and cheaper works generally might be adopted; sharper curves might be laid down; very heavy gradients, particularly in mountainous regions, might be more cheaply avoided; and lighter engines with lighter vehicles might be made to do all the work, where high speed was not demanded, and where the traffic was not heavy.

The Norwegian government, as appeared from a report by Mr. C. D. Fox, had in operation two lines on a gauge of 3 ft. 6 in., one from Grundsett to Hamar, 24 miles long, the other from Trondlijen to Staren, 30 miles long. The former, with gradients of 1 in 70 and curves of 1090 feet radius, had cost, including rolling stock and stations, £3000 a mile. The latter, through a more difficult country, with gradients of 1 in 42, and curves of 700 feet to 1000 feet radius, had cost £6000 a mile. The engines weighed 14 tons in steam, and the speed was about 15 miles an hour including stoppages. A further length of 56 miles was in course of construction, and no other gauge was contemplated for the traffic of that nation.

It was, however, illegal at present to construct any passenger lines in Great Britain on a narrower gauge than 4 ft. 8½ in., or in Ireland than 5 ft. 3 in. Consequently, it would appear to be desirable to endeavour to obtain the repeal, or at least a modification of the provisions of the Act 9 and 10 Vict., cap. 57, which regulated the gauge of the passenger lines, as there was now an increasing demand for railways of a minor class. Many coal and mineral lines on a less gauge than 4 ft. 8½ in. were in use, and others were projected, with ultimate views of passenger traffic; and it would be advantageous if some narrower gauge were recognised. Whether the exact gauge should be 2 feet, 2 ft. 6 in., or 3 feet, or any other dimension, it was believed there could be no question that a system of branch lines costing two-thirds of those now ordinarily constructed, and worked and maintained at three-fourths of the expense, would be of great benefit to Great Britain and in Ireland, and would be most valuable in India and the Colonies—in fact wherever there were people to travel, produce to be transported, resources to be developed,—in cases in which it would not be commercially profitable to go to the expense, at the outset, of a first-class railway.

ON FACTORY CHIMNEYS.

By Peter Carmichael.

(With an Engraving.)

The importance of an effective chimney need only be named. On it depends in a great measure the success of the firing, so as to raise steam quickly, and keep it up steadily, and also the perfect combustion of the fuel with the least amount of smoke. With a draught in the chimney less than $\frac{5}{10}$ths on the pressure gauge, the firing of the furnaces will in most cases be a constant toil to the fireman. He cannot avoid making a large quantity of black smoke, and in cases of an extra demand for steam it is impossible to meet it; for no stirring or coaxing of a fire will make it burn brightly, or produce the red glow which is the perfect condition for raising steam, without a full command of draught. It is difficult to make experiments, but it would be very instructive to have a number of observations or tests of various chimneys, to ascertain the temperature of the escaping products, and the force of the draught; giving along with these the dimensions of the chimney, and the work done, that is, the number of boilers and furnaces, and the coals consumed in a given time. In what follows notice will be taken of all these points in detail.

My experience is, that most factory chimneys are too large for the work they have to do; not too high (they can hardly be that), but too wide, especially at the top. In our practice, invariably as more boilers and furnaces have been added to a chimney the draught has been improved; and it is obvious, that if the opening in the chimney be too large, compared with the whole of the openings in the dampers passing into it, the draught will be reduced. Hence it is very noticeable, in many chimneys which are large in proportion to the number of furnaces they serve, or the coals consumed, or where a new chimney is put up to serve for prospective additional furnaces, the smoke issuing from such has a very lazy ascent, and they are generally blackened a long way down from the top by the smoke; for when a breeze is blowing, the smoke, instead of ascending, falls down the leeward side of the chimney, and clings to it like a ragged black flag.

I have recorded observations made from time to time for several years on the temperature of the escaping products of combustion in the flues and at the bottom of the chimneys, and have also taken notes of the force of the draught, both of which are important elements in considering the value of a chimney for doing its work properly. The temperature is obtained by using small strips of the following metals:—Zinc, which melts at 700°; lead, 600°; bismuth, 500°; and tin, 440°. Small bits of each of these, about 1 inch long and ½ inch broad, are pierced with a hole for passing a wire through, and suspended in the flues behind the damper, or at the bottom of the chimney, and the time noted when they are melted. From these observations frequently repeated, and tried under various circumstances, it has been found that the temperature is nearly uniform at 600° behind the dampers; 440° melts at once, 500° generally in less than a minute, 600° melts when the fires are in good condition, and 700° does not melt. So unvarying are these results under different circumstances, that I assume 600° at the bottom of our chimneys as a standard of temperature of escaping products. This seems a great loss of heat with a steam pressure on boilers of 35-lb.

For testing the force of draught the ordinary water-gauge is used, but on a very enlarged scale, so as to ensure as much accuracy as possible. The mode of arrangement will be seen without much explanation, by reference to the drawings of the instrument, Fig. 10, Plate 12, which is an elevation, and Fig. 11, a section thereof.

The reservoir is a tin flagon, 5 inches by 4 inches. The glass indicator tube is ½-inch bore, being a bit of a boiler water-gauge, and the scale adopted is an inch divided into tenths. A piece of pipe is inserted in the chimney, having a stop-cock and an end turned up, and made for the draught-gauge fitting into. The small hole in the stop-cock, as shown in the section, is for allowing air to get in, so as to nicely adjust the scale to the level of the water. When the stop-cock is turned to open communication between the draught and glass tube, the height is readily read off by a practised eye in decimals.

The accompanying drawings represent three chimneys at Dens Works, Dundee, differing in size, but of nearly the same general proportions. No. 1 (the largest), is represented in the elevation, Fig. 1, and Fig. 2, a section thereof; there is also a plan, Fig. 3, of the taper-top; Fig 4, a base plan; and Fig 5, a plan of the top, which has an outlet surface of 25 square feet. There is no claim made to originality in their shape, as previous to the erection of No. 2 chimney, in 1844, there were several throughout the country, particularly a very handsome obelisk, built with stone, at the works of Messrs. Marshall & Co., the emminent flax spinners at Leeds.

The taper-top is found to answer the purpose well, the smoke ascending from it very freely, especially when there is a breeze of wind. At such times the ordinary top is acted on like a key when blown into to make it whistle, the blasts of wind affecting very perceptibly the draught of the furnaces. In the taper-top this is not much felt, as the wind can only blow into one or two of the four compartments at a time, and this still allows the other two to vent freely.

No. 1 was built in 1854 to replace an old low chimney. It is situated on the top of a brae, above the boilers and furnaces which it supplies. It is 162 feet from base to top, and from the firing level of the first 15 boilers to base of chimney there is a rise of 63 feet. At a lower level there are other four boilers 86 feet below the base of chimney, so that the total height of the 15 boilers from firing level to top of chimney is 225 feet, and of lower four boilers 248 feet. From both of these ranges of boilers the smoke is conveyed to the chimney by a long sloping brick flue or tunnel, mostly underground.

As the drawings are to scale, it is not necessary to go into details on them. Suffice it to say, that the opening at base of No. 1 is 9½ feet square, at top 6 feet square, but the opening at top is still further contracted by the cross walls for carrying the taper point. The area at bottom is, therefore, 90·25 square feet; at top 36 square feet; contracted at outlet to 25 square feet.

For further data it may be stated that the 19 boilers, each with two furnaces, the flues of which pass into this chimney, have an area for each boiler, at bottom of chimney, 4·75 square feet; at outlet of chimney, 1·31 square feet.

The consumption of coal for each boiler is about 11 tons per week, the average consumption being about 210 tons of coal consumed for 60 hours' work of engines, all told, from getting up steam on Monday morning till Saturday, or about 3½ tons per hour. These statements are given for the purpose of showing the actual duty done by this chimney and for comparison. The draught of this chimney has been tested over the period of a year or two, there being 90 observations recorded in all. At the bottom of chimney, the highest recorded is ·88.; the average is ·8; the lowest is ·55.

In taking the observations the height of barometer was noted, and the direction of the wind. The changes of the barometer do not show much effect on the force of draught, it seems most affected by the wind, being lowest in a south or south-west wind.

The chimney No. 2 (shown in elevation at Fig. 6 and section Fig. 7) built in 1844, to replace an old one that stood in the way of extension, is 135 feet high from base to point. The opening at base is 7 feet square, and at top 4¼ feet square, the outlet at top being further contracted by cross walls, so that the area at bottom is 49 square feet; at top 18·06 square feet; contracted at outlet to 13·78.

There are 7 boilers, each with 2 furnaces, the flues of which pass into this chimney, the furnaces being about the level of the base of the chimney, giving an area for each boiler, at bottom of chimney, 7 square feet; at outlet, 1·96 square feet.

The consumption of coal is nearly the same for each boiler as formerly named, say 11 tons per week, or an average of 75 tons for 60 hours' work, all told, from getting up steam on Monday till stopping on Saturday.

The draught of this chimney has been tested as regularly as the large one, and there are 94 observations recorded in all. The highest recorded is ·875; the average, ·75; the lowest, ·6.

The chimney No. 3, built in 1864, was made as small and light as possible, being intended to supply only a few boilers. It is 102·8 feet high from base to point, the opening at base is 4·25 feet square, at top 1·5 feet square, the outlet at top being further contracted by cross-walls, so that the area at bottom is 18·06 square feet; at top, 2·25 square feet; at outlet, 1·75 square feet.

There is only one boiler as yet connected to this chimney, the furnaces being at the level of the base, giving an area for the one boiler, at bottom of chimney, 18·06 square feet; at outlet, 1·75 square feet. The consumption of coal for this boiler is about 10 tons per week, varying with the work done.

The draught of this chimney has never been so good as the others; there have been 31 observations recorded. The highest is ·537; the average is ·5; the lowest is ·45.

In building this chimney, a few holes were left in each side of the square near the top, like pigeon-holes, but sloping acutely drawup (see drawing), in the hope that the wind blowing into these, the current being thus directed upwards, they would assist the rising of the smoke. Hitherto they do not seem to affect the purpose desired, but rather have a bad effect, the smoke issuing from them blackened the top of the chimney a greater distance down than the others.

In drawing comparisons between these three chimneys, a table might be made to show more clearly the distinctive differences; but the number being so few, it is hardly worth while to elaborate the inquiry. At the same time, perhaps, enough has been given to indicate something near the size that a chimney should be for the work it is intended to do.

In the large chimney (No. 1) the quantity of work done is an extreme case, and our experience of it has been that it has become more efficient as boiler after boiler has been put to it. On the other extreme, the No. 3 chimney (shown in elevation Fig. 8, and section Fig. 9), serving only one boiler, although made very small for its height, has a very weak draught, and is evidently too large for the work it has to do. If additional boilers are required to be added, there is no doubt but it will improve, and be better fitted for its work.

There was a violent storm of wind at Dundee, on Saturday, February 13, 1864, which is taken notice of here because it gave an opportunity of making some observations on the chimneys. At the height of the gale, which fortunately was between two and three o'clock in the afternoon; when most of the work-people had gone home, the tops of both the chimneys No. 1 and 2 were blown down at the same instant, making almost a simultaneous crash in falling, all the taper-top being carried away in both cases without injury to the square shafts of the chimneys. The gale was more violent than had been experienced for at least twenty years, as was evident from it blowing down the top of No. 2, which had stood since 1844, and also by the destruction to other chimneys and buildings in the district. Being present at the time, I was anxious to see how the chimneys behaved in such a violent storm; and this was seen, to some extent, by looking at No. 1 in line with the corner of a high mill, keeping the head steady. The movement was plainly visible; not a swaying motion, like a tree bent by a blast, and recovering itself during the lull; but a steady rocking motion like the swinging of a pendulum. The oscillation did not appear to exceed 12 inches, and the observations gave a feeling of security as to the stability of the chimney. The tops of these chimneys were not rebuilt for some months, having to wait until the fires were out for a few days at the annual holidays. In rebuilding, the bricks were made to models in much heavier pieces than before, and dovetailed together, as shown in the plan.

While the tops were off there was not much difference in the draught, the cross walls at top not being injured; but there was more dark smoke than before or after, and it did not rise so freely, but in a breeze of wind fell down the leeward side, and clung more to the chimney.

When the tackle was up for getting to the top of No. 2 chimney, the opportunity was taken to make some observations on the heat of the escaping products, and also to see how much the outlet at the top could be contracted without injuring the draught. With a view to this the draught was tested for several days with the water gauge, and it showed fully ·8, and at the same times the height of flues was tested; at bottom of chimney 500° melted in one minute, 600° melting in longer or shorter time, depending on the state of the fires. Expecting that the temperature would be much lower at the top of the chimney, the operator was supplied with the alloys melting at 212°, 286°, and 367°. These melted very quickly. Then 440° and 500° were tried, when both melted in a little more than two minutes; 600° would not melt, thus showing the temperature of the escaping products at the top of the chimney to be between 500° and 600°. A sheet of iron was then put on the top of the chimney, contracting the outlet 2¾ square feet. This was tried for two days, and did not affect sensibly either the draught or the temperature. The outlet was then contracted still further by a larger sheet covering 5·48 square feet. This had a perceptible effect on the draught. The experiments were not carried further, there being considerable difficulty and some danger in following them up. By contracting the outlet with a proper taper, instead of merely laying on a flat plate, the contraction might have been carried still further.

The greatest want of draught is occasionally on Monday mornings, after a cold wet Sunday. In such cases the flues and chimney are cooled down, and the draught greatly reduced, so that the firemen have much difficulty in getting the fires to burn brightly, and keep up the supply of steam. Sometimes, in the setting of the boilers, and even in the chimneys, there are open joints which admit cold air, and are very injurious to the draught, and the openings for dampers working in are often very wide, and admit more cold air than need be. The draught gauge is very useful in detecting any falling off from such causes, and in the hands of the skilful engineer should in some small degree be like the steam-engine indicator.

THE EXHIBITION OF WATER-COLOUR DRAWINGS AT THE EGYPTIAN HALL, PICCADILLY.

Owing to pressure upon our space last month we were compelled to omit our intended reference to this exhibition, now opened for the first time in the Dudley Gallery. Its promoters have had for their object the establishment of an institution, which, while exclusively devoted to drawings, as distinguished from oil paintings, should not in its use by exhibitors involve membership of a society. In this respect it differs from those already in operation in London; the Water-colour Societies reserving their walls entirely for members, while those galleries which are comparatively open to all exhibitors (such as that of the Royal Academy) afford but a limited and subordinate space to all works in other materials than oil.

The experiment thus made bears every indication of proving a success. In the first place the responses to the application have been very numerous,—far more so than there has been any possibility of accommodating,—and nextly, this superabundance has enabled the committee to place on the walls a highly select as well as interesting collection, which has gradually increased in public favour the more it has become known. There is no branch of the fine arts in which as a nation we so much excel as in painting in water-colours, and the appreciation of this art has extended far and wide among all classes of persons, so that a demand has been imperatively created such as is hereby met, and which presents such unequivocal signs of merit, that we shall hope for the annual recurrence of this exhibition.

The subjects are 519 in number, and consists principally of landscapes; the total number of contributors being somewhat under 250, including not a few ladies. Among the latter Miss H. Coleman holds a distinguished place, both in point of talent and variety; (439) the "Kingfisher," by this artist, is especially noticeable. Miss Blunden has four very good works,—transcripts from Wales and the South of England; and Miss R. Solomon several clever pictures which can hardly escape attention.

Mr. H. W. Brewer gives a capital delineation of the Western Porch of Ratisbon Cathedral, (4); while Mr. McQuoid is as architectural and truthful as ever in each of his efforts, of which perhaps the two (5, 356) from Caen, Normandy, are the most striking. An agreeable sketch of the Mosque of the Sultan, at Cairo, forms the subject of (15), by Mr. Frank Dillon; and a kindred work (39) by Mr. Pilleau, gives a curious insight into the street architecture of that place. Ancient Greece has supplied Mr. G. Hering with a view (49) of the temple of Jupiter Olympius, near Athens, which is well drawn, but rather crudely defined; and from the same country Mr. H. Johnson furnishes (150) a view of the well-known Acropolis at Athens. Warwick Castle and Mill (158) by Mr. Aston, is a favourate scene well handled, yet hardly so successful as an adjoining picture by Mr. E. Dolby (171), representing the "Castle of Falaise, Normandy." Normandy too has invited the pencil of Mr. Lennard Lewis, who in (231) exhibits an excellent view of the Church of St. Wulfran, Abbeville.

The "Thames Embankment at Westminster" (245), by Mr. A. Severn, is a large picture, which bears evidence of such conscientious rendering as will make it a permanent record of that vast undertaking in one stage of its progress; and, travelling once more abroad, we observe (325), Mr. F. Townsend's attractive delineation of the Temples of Pæstum, forming a kind of panorama. The views of the Cloisters at Tewkesbury Abbey (140), by Mr. Niemann; and of Rievaulx Abbey (278), by Mr. Johnson, are antiquated in their effect to an undue degree, and thereby lose instead of gain in point of interest.

Among less architectural subjects we may mention Mr. Richardson's two capital interiors of a Highland Cottage (48, 83); Mr. Stanners' view near the Land's End (77), elaborated with Preraphælite minuteness; Mr. Needham's clever sketch at South Brent (105); also his "Ivy Bridge" (165); "Snowdon," from Capel Curig (145), by Compton Warner; "Zobeide in the Island," from the Arabian Nights (134), by Mr. T. Dalziel; the Views of Nice (173), by W. Nash, jun., another essentially minute achievement; a beautifully delicate glimpse of the "Arno at Florence" (177), by Mr. J. C. Moore; and Four Studies on the Sussex Coast (391), by Mr. Mogford.

Mr. W. Beverly, the well known scene-painter, has five charming productions, especially (66), "Burlington Fishing Boats," to which a powerful rival in attraction is found in (65), Mr. Arthur Severn's masterly representation of "Waves by Moonlight," one of the most original and extraordinary pictures in the exhibition, a remark which applies in a less degree to Mr. G. Mawley's "Interior of an Old Barn" (211), one out of several welcome contributions by that skilful artist.

THE COMPULSORY SALE OF LAND REQUIRED FOR PUBLIC UNDERTAKINGS IN ENGLAND.*

Railways Clauses Consolidation Act.

The legislative provisions relating to compensation and other matters which we have hitherto had under consideration apply equally to all undertakings for which compulsory powers to purchase lands have been obtained. There are, however, other cases for compensation which arise especially in relation to railway works. These, among other things, are provided for by "The Railways Clauses Consolidation Act, 1845" (8 Vict. cap. 20). And this act as well as the Lands Clauses Act, is incorporated in all special acts for making railways. The following is a summary of the provisions so far as they relate to our subject.

* Continued from page 65.

Temporary use of Lands.—The company may at any time before the expiration of the time limited by the special act for the completion of the railway, enter upon and use any existing private road within the limits of deviation, or, if no limits be prescribed, not being more than 500 yards from the centre line of railway delineated on the plans, and being a road formed with stones or gravelled, and not an avenue, or a planted or ornamental road, or an approach to a mansion. Before entering upon such roads the company must give twenty-one days' notice of their intention to the owners and occupiers of the road and of the lands over which it passes, and state in such notice the time and purpose for which they intend to occupy it, and also pay to the parties interested, either in a gross sum or by half-yearly instalments, such compensation as may be agreed on, or settled by two justices in case of difference between the parties.

Within ten days after service of such notice by the company the owners and occupiers, by notice in writing to the company, may object to the road being made use of, on the ground that some other public or private road would be more fitting to be used, and thereupon such proceedings may be had as are presently to be described in the case of the temporary occupation of lands.

At any time before the expiration of the time limited for the completion, the company may, without making any previous payment, tender, or deposit, enter upon lands within the prescribed limits, or if no limits be prescribed, not being more than two hundred yards from the centre line of railway as delineated on the plans, and not being a garden, orchard, or plantation attached or belonging to a house, nor a park or avenue, or ground ornamentally planted, and not nearer to the mansion-house of the owner of any such lands than the prescribed distance, or if no distance be prescribed then not nearer than five hundred yards therefrom. They may occupy such lands as long as may be necessary, and use the same for taking earth or soil therefrom, for depositing spoil thereon, for obtaining materials therefrom for the construction and repair of the railway or for the purpose of forming roads thereon to or from the railway. They may erect on the said lands temporary workshops, sheds, or such buildings, dig clay, stone, gravel, &c., and manufacture and work any kind of material thereon used in the construction of the railway; but no quarry, brickfield, or like place, so used at the time of the passing of the special act, can be taken or used by the company for any of these purposes.

If any such lands are required for spoil-banks, side-cuttings, or obtaining materials, the company before entering thereon (except in case of accident to the railway) must give twenty-one days' notice in writing to the owners and occupiers, and if for any of the other purposes mentioned, they must give ten days' notice of their intention to enter.

The notice must be served on the owners and occupiers personally, or left at their last known place of abode; and if the owner is absent from the kingdom or cannot be found, the notice must be left with the occupier for him, or if no occupier, then affixed on some conspicuous part of the land.

In any case in which the twenty-one days' notice is required, the owner or occupier may within ten days object, by notice in writing to the company making use of the lands, either on the ground that the lands proposed to be taken are essential to be retained by the owner, in order to the beneficial enjoyment of other neighbouring lands belonging to him, or on the grou d that other lands lying contiguous would be more fitting to be used by the company for the purposes indicated.

If the objection be made on the ground that the lands proposed to be taken are essential to be retained by the owner, any justice may, on the application of the owner, summon the company to appear before two justices, at a time and place to be mentioned in the summons, the time not being later than the expiration of the twenty-one days' notice. On inquiring into the truth of the objection, the justices may order that such lands or some part thereof shall not be taken or used by the company without the consent of the owner.

If the objection be made that other lands are more fitting to be used, any justice may, on application of the owners, &c., as before, summon the company and the owners of such other lands, at some time not more than fourteen days after the application, or less than seven days after the service of the summons.

The justices may then determine summarily which of the lands shall be used, and authorise the company to occupy and use them accordingly, or they may if they see fit adjourn the case, and summon before them any other party whose lands may appear to them to be fitting, and afterwards finally determine whose lands shall be used.

Before entering on any land required for spoil-banks, side-cuttings, obtaining materials or forming roads, the company, if required by the owners or occupiers, must find two sufficient persons to enter into a bond, in a penalty of such an amount as shall be approved by a justice if the parties differ, and conditioned for the payment of such compensation as may become payable for the use of the lands. The company must also put up such fences and gates to the lands or roads used by them as two justices may deem necessary, in case of difference between the parties.

Any lands taken for the purpose of getting material are to be worked under the direction of the surveyor or agent of the owner, or, in case of disagreement, in such manner as any justice may direct, on application of either party.

In all cases where the company enter on lands for the purpose of making spoil-banks, or side-cuttings, or getting materials, and at any time while the company are in possession, the owners or occupiers (if they have not accepted compensation for the temporary occupation), may serve a notice on the company, requiring them to purchase their estate and interest in the said lands. In such notice the particulars of their interest and the amount of claim must be set forth, and the company on service of such notice are bound to purchase the lands or the estate and interest therein of the parties so giving them notice.

When the company are not required to purchase the lands, it is incumbent on them, within one month after entry, to pay to the occupier the value of his crops or dressings, and full compensation for any damage of a temporary nature; and also from time to time during the occupation to pay half-yearly to the owner or occupier, as the case may require, a rent, to be fixed by two justices if the parties differ; and also within six months after they have ceased to occupy the lands, and not later than six months after the expiration of the time for completion of the railway, pay to the owner or occupier, or deposit in the bank according to the circumstances, the full compensation for permanent or other loss, damage, or injury, that may have been sustained, and the full value of all materials taken.

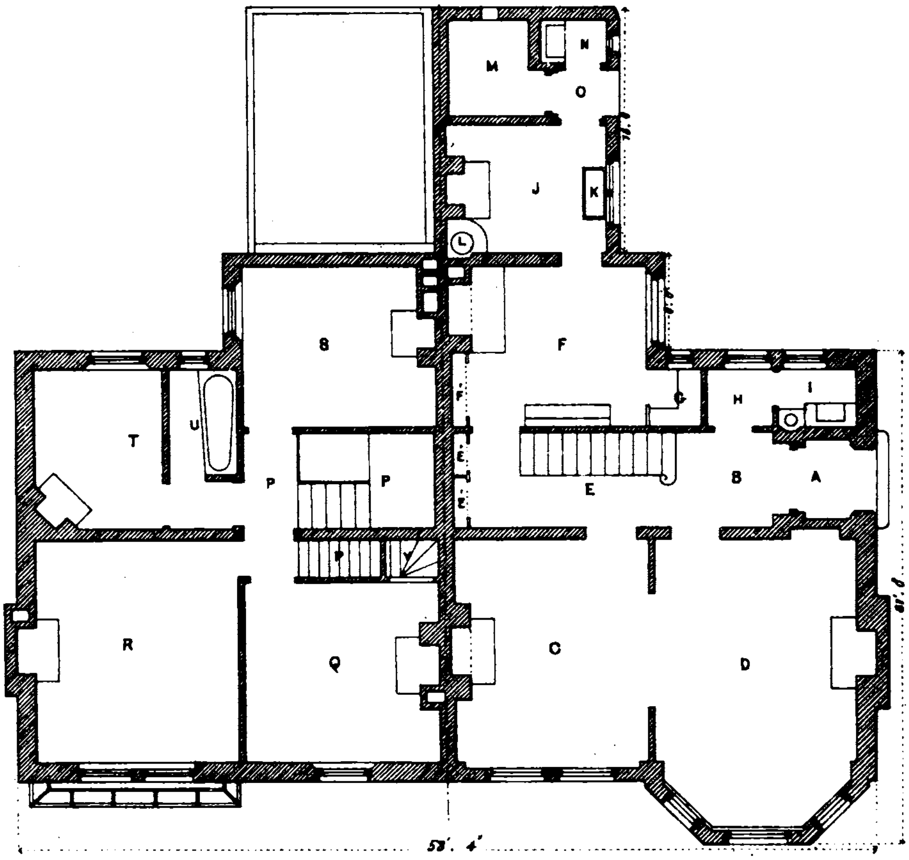
In addition to lands authorized by the special act to be compulsorily taken, the company is empowered by the Railways Clauses Act to contract with any party willing to sell the same for the purchase of any land adjoining or near to the railway, to be used for extraordinary purposes, such as additional stations, yards, wharves, warehouses, roads, &c.; the number of acres to be ac quired for these purposes is limited, according to circumstances' by the special act.

Mines, &c.—A railway company are not entitled to any mines of coal, iron, stone, slate, or other minerals under any lands purchased by them, except such as are necessary to be dug or used in the construction of the works, and all such mines and minerals, unless they have been expressly purchased, are deemed to be excepted out of the conveyance. There are special provisions with regard to the working of mines under or near the works of the railway. If the owner or occupier desire to work a mine lying under a railway, or within forty yards of the same, he must give thirty days' notice of his intention to the company, who may cause the mines to be inspected, and if it appear to them that the working is likely to damage the railway, and they are willing to pay compensation, then the owner is not to work such mines. If before the expiration of thirty days after notice served the company do not state their willingness to treat for the payment of compensation, the owner may work the mines in a proper manner; but if any damage or obstruction be occasioned to the railway or works by the improper working of the mines, the owner or occupier is liable to make good such damage, or in default the company may make good and recover the cost by action at law.

The company on giving twenty-four hours' notice in writing may enter and inspect the working of mines near or under the railway; and if improperly worked may give notice to the owner or occupier to take proper measures or execute proper works for the security of the railway, and in default may execute the same themselves, and recover the cost from the owner or occupier by action.

The amount of purchase money or compensation payable by the company in cases under this act is settled in the same manner as provided for disputed cases under the Lands Clauses Consolidation Act.

(To be continued.)



Half Plan of 1st Floor. Half Plan of Ground Floor

J R Jobbins

SEMI-DETACHED VILLAS, BALHAM, SURREY.

VILLAS, BALHAM, SURREY.

(With an Engraving.)

The subject of our illustration was selected, out of about fifty submitted in a recent competition at the invitation of Mr. Edwd. Ryde, for the best design for a pair of semi-detached villas, to cost about £1000 the pair, of character suited to a superior class of tenant. The plans show the general accommodation on the ground and first floors, being respectively 10 feet and 9 feet high, in addition to which are two good attics in each house, 7 feet high to the plate of the roof, and 10 feet in the clear height. Considerably increased area is given to the drawing-rooms by the addition of bay and bow windows, and these rooms may be thrown *en suite* with the dining-rooms by raising the large door, which is hung to slide up into the partition above, thus avoiding the inconvenient and unsightly opening and closing of folding-doors. The door is so framed as to admit of a section opening as an ordinary door of communication.

The fronts are faced with picked stocks of dark grey tone, the bands and arches over the windows of white brick, with Box-ground stone springers, mullions, cills, cornices, &c., and molded brick bed mold in the cornice and chimney caps. Taylor's patent brown-ware drip-band is introduced under the cills of the attic windows, as a protection to the thinner part of the wall. The roofs are covered with Taylor's patent tiles, "dulled red in the kiln:" the molded eaves-gutter and the central down-pipe, which is of ornamental character, are the manufacture of Messrs. Macfarlane, of Bedford-street, Strand. The architect is Mr. T. C. Sorby, of Bedford-row, London.

References to Plans.

HALF PLAN, GROUND FLOOR.

A. Entrance porch.	G. Larder.
B. Hall.	H. Lobby.
C. Dining-room, 14′ 0″ by 12′ 0″	I. Watercloset and lavatory.
D. Drawing-room, 18′ 0″ by 12′ 6″	J. Scullery, 10′ 0″ by 8′ 0″
E. Staircase.	K. Sink.
E′. Closets.	L. Copper.
F. Kitchen, 12′ 0″ by 10′ 0″	M. Coals.
F′. Closet.	N. Watercloset.
	O. Porch.

HALF PLAN, FIRST FLOOR.

P.P.P. Staircase and landing.	T. Bedroom, 8′ 0″ by 10′ 0″
Q. Bedroom, 12′ 2¼″ by 11′ 3″	U. Bath-room, 4′ 6″ by 7′ 0″
R. Do. 14′ 0″ by 12′ 6″	V. Closet.
S. Do. 12′ 2¼″ by 10′ 0″	

THE ARCHITECTURAL EXHIBITION.

The opening of this Exhibition having taken place this year at a later period than usual, we were unable to give any notice respecting its contents in our last number, and as it periodically closes on the 30th June, our remarks upon it must be condensed within the limits of the present article, and consequently be less diffuse than under ordinary circumstances. The annual conversazione and private view was held, as heretofore, on the evening before the public opening, being the 2nd ult., and was very well attended. A brief report, as to the status of the exhibition, was read by one of the secretaries, showing somewhat of an improvement upon that of last year; and some well-timed and judicious remarks fell from the chairman, Mr Beresford Hope, the newly elected President of the Royal Institute of British Architects, and from other gentlemen.

With the Architectural Exhibition is this year associated, in a separate room, that of the "Photographic Society," embracing a highly important series of illustrations of that art in various forms, and especially some new developments in its productions, from the experienced hands of Bedford, Thompson, Cundell and Downes, Robinson, England, V. Blanchard, and others. The photographs, taken from life, of the animals in the Zoological Gardens, by Mr. Haes, of the Haymarket, form an attractive collection.

As regards the total number of contributions to this Architectural Exhibition, we observe that it is almost precisely the same as to the last, both in reference to the pictures, and to the objects in the department of Practical Art, there being 400 in the former, and 38 in the latter. A glance round the rooms will discover, as noticeable, a greater variety of subject and a higher standard generally in the detailing of the better class of works. This special advance is to be found, as might be expected, among the junior members of the profession—men who allow study and experience to go hand-in-hand, and are not slow to avail themselves of the facilities, everywhere so abundantly afforded in this age of progress. We cannot but note, however, a certain tending to exaggeration, not so much in the way of the general outline of new buildings, as in sundry phases of their details, more particularly, perhaps, in the way that colour is introduced, be it in the shape of constructive materials, or superadded decoration. To apply a now well-known and expressive word, it is too "sensational;" a striving after, and gaining too, a degree of novelty in effect, not always by the most thoughtful and legitimate means. This tendency to an extreme, little dreamt of a few years ago, should unquestionably be checked, otherwise architecture, proper, loses its position, and art is no more art. There is also an evident increase in the tendency to producing *ad captandum*, rather than purely architectural drawing, which by how much they represent things in an artificial or conventional manner, by so much they detract from their purity and real value. Thus, give a number of artistic draughtsmen or colourists the same outline to work upon and finish, and what an amusing variety of interpretation would be the result. One would show all the varieties of positive colour; another would deal only with grand masses of light and shade; a third would devote his chief care to picking out and elaborating details; a fourth would choose the fanciful pen-and-ink style, with strong back-lines and weather-stains, which has of late been so much patronised; while but a very few would content themselves with the unsophisticated outline as practised a century ago, in which the shadows are simply washed in with a light tint of sepia or india-ink. We advocate, not a return to such utter crudities as these last, which, though more satisfactory to a thoroughly experienced eye, are as far from conveying a correct impression to the less initiated, as are some of the other methods to which we have referred.

The first drawing on the walls, by Mr. W. Harvey, may be referred to in connection with a subsequent one (326) by Mr. Kerr. Both represent designs for the new buildings and museums at South Kensington, the latter being, as our readers will remember, a premiated one, here shown in the general elevation only, which, in spite of much that is decidedly *outré* in some parts, as a whole is marked by considerable dignity and grandeur. Like that just mentioned, Mr. Harvey's is Italian in style, and in its composition the critic will detect gleanings from various already executed foreign works; and though these are cleverly interwoven, the force and originality which such a composition would otherwise present are proportionately lost. Equally noticeable, but more original, is Mr. F. P. Cockerell's design submitted in the same competition, here represented by a portion of the elevation (87), and a perspective view (88). The style in which these drawings are prepared is in itself peculiar, being done on a dark grey paper, with the high lights brought out in body white. The whole effect is gloomy and unattractive, and thus its many meritorious points are likely to be overlooked. Mr. Porter, too, is an exhibitor (143) of a design for the same public building.

In No. 6, Mr. Digby Wyatt gives a group of 19 original sketches for terrace garden-works at Castle Ashby, chiefly studies for the arrangement of steps and balustrades, and carefully designed in keeping with the fine old mansion. Mr. Wyatt also gives (115—120) a tolerably perfect set of general working drawings for a mansion, lodges, &c., to be erected at Norwood, which gives promise of a very convenient and satisfactory-looking building. The Chester Town-hall competition is represented partially by several of the candidates, the first on the list being by Messrs. Hay. We are sorry we cannot compliment the authors of this design, which is at best but a feeble effort in Gothicised Italian. The ceiling to the great hall is perfectly flat, and arranged in shallow oblong panels of the poorest description, while the details shown on the drawing for the principal staircase are quite out of character. Mr. Tasker has prepared an excellent half-timbered house for Mr. Birket Foster, of which numerous illustrations are given (13 and 61). These are given in photography.—"The Dining-hall at Shadwell Court," for Sir R. J. Buxton, by Mr. Teulon (14) is, like every other work of the same author's, quite *sui generis*. His several other drawings on the walls are as much beyond sober criticism as this is. Individuality and a degree of picturesqueness they may claim, but this is at the sacrifice of nearly every other medium of orthodoxy, so far as the received canons of art are concerned.

The seven beautiful drawings (16—22) by Mr. Blomfield, will convey pretty accurately the minutiæ as well as general conception of his elaborate design for the Grocer's Hall, London,—submitted in the recent select competition for its rebuilding. It may be remembered that a handsome premium was bestowed on each of the gentlemen who sent in, but that no design was eventually chosen. That by Mr. Blomfield, which is the only one on the walls of the professedly Architectural Exhibition, though two others are in part represented in the Royal Academy, is founded on strictly Mediæval examples, being more servile in its features than the inventive skill of the author usually allows. Where he has trusted most to himself he appears to have been most successful. It is therefore a matter for regret that he has so closely followed much of that type of architecture which has been so ably interpreted by M. Viollet-le-Duc, and other authors. The site was a most awkward one, but in this the availableness of Gothic principles was especially apparent, a fact greatly to the advantage of Mr. Blomfield, Mr. Scott, and other architects of that stamp. The least happy part of the conception is the front elevation towards Princes-street, which seems to want greater dignity of form and unity in composition. The interior of the great hall shows a fine room, with an elaborate open-timbered ceiling, or roof, for such it certainly is, the decorations of which are highly elaborated, without being unduly prominent.

Mr. W. White's contributions invariably are of the most unobtrusive kind, so far as delineation is concerned, but there is usually much satisfactory study evinced, especially in the plans. Mr. White is of the severely Gothic school, and his elevations partake of this element, and there is in them a certain awkward look of extra quaintness to which it is difficult to assent. The several works by this gentleman to be found on the walls will bear out our meaning. In a totally different style runs the current of Mr. Owen Jones' ideas (as need scarcely be remarked), with him colour is the essential, and he has done good service to this branch of art in various ways. We have now before us (29, 30) the decorations for the Chinese and Indian courts of the South Kensington Museum, showing the main arcade, and a portion of window and wall surface. In these, green and red tints are employed for the ground work, but for the spandrel spaces, and upper part, a rich but quiet scroll diaper is superadded with good effect. Four large drawings exhibit Mr. Holmes' accepted design for the new Masonic Hall and Club, Birmingham; a by no means prepossessing looking affair, and which certainly has not received much embellishment at the hands of either draughtsman or artist. The same may be observed respecting Mr. Holmes' New Union Club, Birmingham, (50), here shown as the second premiated design. It is refreshing, therefore, to turn to Mr. E. B. Lamb's Italian designs, which are always distinguishable for their genuine appreciation as to style, and a delightful inventiveness as to composition. In no design of his, that we can remember, are these qualities more displayed than in that for the Ipswich Town Hall, characterised at once by great simplicity of parts and boldness of massing. The deeply recessed entrance, with its sculptured panels along the sides, is a very effective feature. Mr. Lamb's interpretation of Gothic is less successful; witness, the church now being erected by him at Kentish Town, and here shown (53), by a west elevation. Mr. Pullen's design for a Town Church claims attention as much for its gloomy aspect as for its peculiar scheme, which appears intended mainly to provide surfaces of mural decoration, partially relieved by the dim religious light of a few stained glass windows. Mr. Goldie sends several clever Gothic designs, principally for churches, that for a convent at Cork being the most effective. In one for Abingdon (59), a bell-turret is shown at the west-end, which would not appear to be adequately supported. The interior of the church of the Austin-Friars, London, was completely destroyed by fire some time since, and it was thought that the whole of the fabric must be rebuilt. Thanks, however, to the zeal of the archæologists, who took up the matter warmly, the ancient walls have been left standing, and the scheme of re-building was merged into one of restoration, the architects being Messrs. I'Anson and Lightly. The whole of the accommodation is provided for in the nave, which is inclosed by oak screen-work of somewhat poor design, nor do the fittings generally appear so well designed as they might have been for such a building.

In the class of pen-and-ink drawings there is nothing in the exhibition which can bear naming with those by Mr. Norman Shaw, for the proposed new Exchange at Bradford. Good as were those by Mr. Blomfield, already noticed, these decidedly eclipse them; and without altogether endorsing the ultra-mediævalism and eccentricity of some of the features, there is displayed a mastery of conception and power of delineation of no common order. The bird's-eye view, in particular, exemplifies this. The well-known sketching and artistic powers of Mr. Petit are again shown in several continental and English views, roughly and hastily executed, no doubt, but containing all the essentials of truthful and effective expression. Messrs. Slater and Carpenter show an elevation of their design for the Scotch National Memorial to the late Prince Consort, of which a perspective view appears in the Royal Academy. It partakes of the "shrine" character, reminding one of that now being reared in Hyde Park for the same object, to which, however, it must decidedly yield the palm. Many have been the schemes for either altering or rebuilding the old church at Cheltenham, and some time ago the question was laid open to public competition, when the first premium was awarded to Mr. C. H. Cooke, who now sends two of the perspective views. One of the most remarkable features of the church is a large "rose" window, whose present position offers some difficulty to enlarging the plan. It is therefore proposed to re-introduce this in the west gable of a second north aisle. The lofty tower and spire would remain as now.

As good specimens of "medal" drawings, we may refer to those by Mr. T. H. Watson, for an asylum to accommodate twenty-five pensioners (108-112) to which the Soane medallion was awarded by the Institute of British Architects last year. Mr. Currey and Messrs. Penrose and Goodchild forward some of their competition drawings for the Grocers' Hall, the former being of Italian character, freely rendered, and the latter a very common-place production of the same school. Neither of them is so identified in expression as it might have been with its intended purpose.

Christ Church, Ashford, by Mr. Hubert Austin is the successful result of a competition, and shown in a clever exterior and interior view in pen-and-ink. The style is Early Pointed, the character throughout simple and well arranged. All Saints', Windsor (137), is shown by the architect, Mr. Blomfield, as intended to be completed, and is a very satisfactory Gothic design, with some novel features. The attention bestowed on domestic buildings of the simplest kind is evidenced in various ways, and the Society of Arts have issued a well-digested code of particulars for the guidance of their designers. In accordance with these Mr. Snell has prepared a good working design, which is shown in (140, 148). Much of the comfort to be gained in such dwellings depends on the judicious arrangement of the doors, with respect to the fireplaces, and this is a point which seems to have been well attended to. So also Mr. C. N. Beazley, in (378) gives drawings of other suitable works of the same kind. We may, in passing, refer to the clever design for the Farnham Town Hall and Market House, (153, 155, 163) by Messrs. Penfold and Norman Shaw; as a worthy pendant to that by the latter gentleman which we have already described, a drawing of the building as being erected is shown by the architect, Mr. E. W. Tarn, in (266). Some time since, the curious and very perfect gateway of St. Giles' in the Fields was swept away, in a quiet, and, so far as we know, unnecessary manner, and it is not generally known what has become of the almost unique specimen of ancient carving for which it was particularly noted. Like the only other similar instance with which we are acquainted, that at St. Stephen's, Coleman-street, it represented the Resurrection, and was a very fine specimen of the art at that period, a century or more ago. In (181) Mr. Ayling exhibits a photograph of the former, which will therefore be viewed with interest. The original is carved in wood. Mr. Whichcord, whose experience in hotel-building has now become considerable, shows (188) the Sablonière Hotel, in Leicester-square, as proposed to be erected, or rather remodelled, for the Foreign Hotel Company (limited); and we only regret that more drawings are not included, so as to give the opportunity for better arriving at a conception of the whole design.

A revival of the Liverpool Exchange competition occurs in the beautiful and carefully studied design by Mr. J. K. Colling, exhibited by four of the principal drawings. If we remember rightly, the impression made by this design at the time was considerable, (though it just escaped one of the premiums,) inasmuch as its author had so well weighed the different circumstances of the case, and had so conscientiously adhered to the prescribed instructions of the committee. The interior view of the News' Room, (198) may be cited as a specimen of careful perspective delineation. Mr. Truefitt, in (211-215) sends, as heretofore, drawings of a series of domestic residences, to which he has been architect, and of which, when we state that they evince his usual skill in dealing with inexpensive materials, and making the most of simple picturesque forms, we have said as much as our space will allow. Mr. G. E. Street's single drawing (218), the interior of his new church at Torquay, though well represented, lacks that force which distinguishes most of his works, and is so far a drawback to the effect of a really very masterly design.

The curious old Manor-house at Lower Walterston, near Dorchester, one of the relics of the Jacobœan era, having suffered by fire, has been restored by Mr. R. H. Shout, at the expense of the Earl of Ilchester, and is shown in its present state in (222, 238) Mr. Driver, in his view of the "viaduct and roof wall" of the London, Brighton, and South Coast Railway Company's London-bridge station enlargement, has clearly shown the clever engineering work of Mr. F. D. Bannister. In (230) we have Mr. Sorby's perspective view of his cleverly designed New Town-hall at Bromley (which has already appeared as an illustration in our Journal), and also a view of the old Town-hall, now pulled down. The same architect also shows drawings of some semi-detached villas at Peterborough, which display many good features; also of the chapels at Harrow Cemetery, which are less satisfactory. As a specimen of novelty and good taste in domestic work, the house erected in 1863 at Harrow, for one of the masters of the school, deserves special notice, though it is here only represented by a small photograph. The architect is Mr. C. Forster Hayward. Mr. Hayward also exhibits (204) a masterly design for re-fronting the Bell Hotel at Gloucester, in the Gothic style. Two careful drawings (272, 282) showing details of the Mosaic pavement in Trinity Chapel, Canterbury Cathedral, have been prepared by Mr. Judge, and are worthy companions to others of the same nature which he has exhibited on former occasions.

Among the few subjects of sculpture which find a place on the walls, are some by Mr. Boulton, of Worcester, and an exquisite panel for the "Thomas Memorial," in Llandaff Cathedral, designed by Mr. H. Armstead, and representing the "Judgment of Solomon." Another panel, illustrating the "Delivery of the Law," is given in (275), while (274) shows the completed design for the tomb, by the architect, Mr. J. Prichard. Wyggeston's New Hospital, Leicester, has been the subject of a recent and much vexed competition, for the adjudication of which a professional gentleman was specially employed, who submitted his report and made his awards accordingly. Much to the chagrin, however, of the parties thus singled out, and without any sufficient explanation being given, so far as we are aware, this award has been virtually set aside; the commission for the work having been given to an outsider, who was not even placed; and this successful design is shown in (278, 346). Knowing nothing whatever of the other designs, we are unable to institute a comparison, but much of the good effect of the drawings before us is undoubtedly attributable to the able style in which they are got up, and especially in the colouring.

The Architectural Publication Society contributes (314) its usual quota of selections from its lithographs, which have been very well executed by Messrs. Kell. Some of the subjects, moreover, are of unusual interest. The four elevations of Great Yarmouth Church show to advantage the peculiar features of that noble building, and its successful alterations and restoration at the hands of Mr. J. P. Seddon. Mr. Seddon exhibits also several other works, including designs for Houses, Furniture, and Encaustic tiles. In (337) Mr. Norman Shaw gives a view of part of the new dining-room, and the details of a plaster ceiling at Willesley House, Kent, erected from his designs, and respecting which he states:—"This ceiling is executed in plaster, lined and stamped whilst wet. It was almost entirely done by two country bricklayers, to whom the work was new, and who had never even seen any of it before. Details were sent to them, drawn in pencil to an inch scale, in the ordinary way, and, with very little direction, they set out the various figures full size, and marked all the patterns with a precision and character most remarkable. This drawing is exhibited simply for the purpose of showing that a considerable amount of ornament may be obtained by using the commonest materials, and by employing local labour."

The attention paid to embroidery, of late, has produced some excellent results, and there is very satisfactory evidence of this in (344) the altar frontal for the Radcliffe Infirmary Chapel at Oxford, designed by Mr. A. W. Blomfield, and executed by Messrs. F. Smith and Co., in which the prominent colours of green and crimson are tastefully relieved by delicate forms and tints. Other specimens, manufactured by the same parties, will be found in (399), while (400) shows yet another good specimen, designed by Mr. W. H. Hendry and executed by Mr. Helbronner. Of the "decoration" of the Reredos at Eton College Chapel, executed by Messrs. Harland and Fisher, under the direction of the architect, Mr. Woodyer, and shown in (351), we do not form so favourable an impression; the fault being more in the general arrangement of the design than in the detail of its parts. The same remark applies to their similar work at Worcester College Chapel, Oxford, designed by the architect Mr. Burges (327, 331), embracing the whole surfaces of the walls and ceiling. Mr. J. Drayton Wyatt exhibits (269) a view of the new church recently consecrated at Hillingdon, in which the architect, Mr. Scott, has introduced much successful variety in the design; and also in (363), an effective pen-and-ink drawing of the ancient Lich-gate in Heston churchyard, Middlesex. The Architectural Association forward, as usual, a series of "sketches," contributed by its class of design during the past session, marking a gratifying advance in educated taste, compared with earlier selections; though there is much yet to be studied, and, perhaps, quite as much to *curb*, before many of such paper experiments are fit to become realities. But the tendency is a hopeful one.

With a reference to the painstaking handiwork of Mr. C. N. Thwaite, in producing the beautiful cardboard models of churches and houses shown in (391-395), and his equally successful plaster model of Kettering Church (396), we must close the present notice, with some regret that for the reason stated at the outset we have been compelled to omit making any allusion to some things that we should otherwise have been glad to have brought under notice; and have almost wholly passed over the numerous copies of old buildings, and certain of the less important modern ones. This may perhaps give an additional stimulus for our readers to visit the exhibition for themselves, and if they are wise they will avail themselves of the season-ticket, which, at the almost nominal price of half-a-crown, will admit at all times to the exhibition, and also to the evening lectures. The subjects and dates of the latter yet remaining to be delivered are as follows:—June 6, "An architect's thoughts," by Mr. E. B. Lamb; and June 13th, "On art foliage," by Dr. Christopher Dresser, while for the 20th a conversazione is announced, which will probably, from its extra attractions, as contemplated, bring together a large assemblage of visitors. The exhibition will terminate on the 30th inst.

In consequence of the length of this notice, our remarks upon the Royal Academy Exhibition are necessarily postponed until our next issue.

THE DOE PARK RESERVOIR, BRADFORD.

In this Journal for April last, some particulars of the Doe Park Reservoir of the Bradford Waterworks Company were given, and also Mr. J. F. Bateman's report thereon. Since that date the adjourned application for a certificate of the completion of the reservoir has been granted by the West Riding magistrates. On bringing this application before the magistrates the town clerk reminded them that, in February last, they had postponed their decision for two months. In mentioning the conclusion to which they had come, they alluded to a passage in Mr. Bateman's report, where he expressed an opinion that the reservoir had not had time to be satisfactorily tested. The intervening season had been one peculiarly favourable to a severe test. There had been a very long frost, which broke up shortly after the day of the adjournment, accompanied by heavy rain, and which resulted in a considerable flood flowing over the waste weir of the reservoir. The reservoir had stood this severe test without any increase in the runs of water beyond what was clearly due to the surface water. The water was then drawn off, in order to ease the valves a little, and since that time the reservoir had been kept just running over. One of the valves had been kept working every day until a few days ago, and they were now in perfect working order, and capable of being drawn up by one man in five minutes.

Mr. A. W. Parry, chief clerk in the borough surveyor's office, took charge of the reservoir on the 23rd February last, and had gauged the various flows of water. That on the west side measured ⅝ths of an inch through a 12-inch notch on March 31, and had gradually increased since then. On the morning of April 15th it measured 1⅜ inches through a 6-inch notch, and it now measured 1½ inch. On the fourteenth there were nine hours' rain. The flow on the east side measured ⅜ths of an inch on the 23rd February, and on Monday last it measured ⅝ths of an inch. —Mr. J. F. Bateman, C.E., had examined the reservoir. Taking the whole reservoir together, the state of things was as nearly as possible what it was on the 27th January. The opinion which he then expressed in his report he must again express; he considered the reservoir quite safe and complete, and the runs of water of no importance as regarded the usefulness of the reservoir for the purposes for which it is adapted.—A Magistrate: In your report of the 8th February, you say, "Still the work of reparation has been very rapidly executed, and though everything at present indicates security, there has hardly yet been sufficient time for perfect consolidation and satisfactory test." Do you now think there has been sufficient time?—Mr. Bateman: I think that the nearly three months which have elapsed have been a satisfactory test. The work remains, as far as I could detect, in a satisfactory state. There has been no settlement in the embankment, no discolouration of the water that did not occur on the 27th of January, no fresh leak broken out, and no increase in the leakage. The leakages or runs of water do not affect the safety of the reservoir in their present condition; and I do not consider there is any danger at all.—Mr. Leather, C.E., Mr. Rooke, C.E., and Mr. Gott, the borough surveyor, gave evidence to the same effect.

NEW WATER SUPPLY FOR CALCUTTA.

A scheme for the supply of water to Calcutta, involving an expenditure of sixty lakhs of rupees, has recently been sanctioned by the authorities. The main features of the undertaking are as follow: the water is to be taken from the river at Pultah, 16½ miles from Calcutta, and to be pumped up twice in the day during five hours at each period of low-water. It will be conveyed by the river water aqueduct to the settling tanks, where it will remain quiescent for a period of 36 hours, after which it will be drawn off from the surface into the filter, from which it will be conveyed by a brick conduit (capable of conveying by a constantly running stream 9,000,000 gallons per twenty-four hours) laid along the side of the Barrackpore-road, 66,600 feet in length, and at an inclination of 1 in 5500, to Tallah, on the Circular Canal, where the water will be received in a covered reservoir, with a capacity of 8,000,000 gallons. Here three 50 horse-power engines will be erected for the purpose of lifting the water to a sufficient height to distribute 3,000,000 of gallons in the northern division of the town during the day time, and 3,000,000 of gallons in the night into a covered reservoir in Wellington-square. Adjacent to Wellington-square, engines will be erected to distribute water under a pressure of 100 feet, to the European and mercantile portion of the community and to the shipping. From Tallah the water will be conveyed into the town by pipes of various sizes according to the requirements of the various divisions. The total length of pipes to be laid will be rather more than 52 miles. The total cost of the water as delivered in Calcutta will be about one rupee per 3000 gallons. This elaborate and comprehensive scheme for the water supply of Calcutta, is the design of Mr. William Clark, the engineer to the municipality.

ARCHITECTURE IN MANCHESTER.

(Continued from page 130.)

Before noticing the chief places of public worship in Manchester and its contiguous borough—Salford—attention may well be called to a few other commercial buildings, that indicate the proneness of the citizens to call in the aid of the architect, and invest even their commonest commercial buildings with such architectural character as they are capable of. Shop frontispieces of good design are to be met with in most English towns; and in Saint Anne's-square, in this city, some elegant shops have been erected from the designs of Mr. Breakspear; but not every town can boast of a well-designed brewery; yet in the neighbourhood of Greenheys and Moss-side, Manchester, may be seen three vast breweries built of homely red brick, and by no means overlaid with ornamentation, which strike the attention of the passer by, telling him by their very outline and combination of parts, that the pencil of the architect has dictated their form and proportions. It is the same with a sugar refinery in Hulme, by Mr. Waterhouse; a drawing of which we remember to have seen in Conduit-street; and in the Leaf-street Baths and Wash-houses, designed by Mr. Worthington. This is as it should be with our English towns. Hardly does any building in this city start up without the suggesting pencil of the architect; of which it is not too much to say,

"Omne, quod tetigit, ornavit."

Would that one could say as much for the buildings of London.

The offices of the Manchester Workhouse Executive, in Cooper-street, claim a word of commendation. This is a small but lofty edifice of "stock brickwork" with stone dressings, designed, we believe, by Mr. Breakspear. The style is Italian astylar, and the proportions and details all carefully worked out with singular delicacy and refinement. The designer was evidently master of the style of architecture he had chosen, and the result is a very pleasing street facade, neither tame nor yet eccentric in its parts.

The villa residences around Manchester and the many manufacturing towns in its neighbourhood, offer far too extended a theme for our critique. A tour round the favourite country spots, such as Didsbury, Cheadle, Bowden, Alderley, Whalley Range, Weaste, Pendlebury, and Prestwich, would give the visitor some idea of the wealth of the principal citizens, and of the pride they take in a well-built mansion and well-kept grounds. Like the banks and warehouses in the city itself, these residences have all the local peculiarity, already adverted to, of being the works of professional architects, and, at the same time, durable structures, faced wholly with stone, or with the most costly brick, relieved with stone dressings. Hardly anywhere is a villa of any pretension to be met with, faced with miserable compo, or "designed" by some speculating tradesman, as is unhappily the case—or rather the rule—in the far lovelier spots about London, such as Barnes, Richmond, Sydenham, Hampstead, and Highgate, where, alas, everything in the shape of building is unsubstantial and ephemeral: either dropping to pieces for want of paint, or undergoing a perennial process of colouring and painting. So that at no one time can a landscape painter find a rural spot in Middlesex (rich though it be in rural beauty), upon which some spick-and-span new compo gate-piers, just newly "beautified and done up," or some crumbling, blackened compo "front," in helpless wrack and ruin, still-born, premature and ghastly, does not stare out of the picture before him, and assert its harsh, crude, offensive unreality. Oh, for some good modern Augustus to rid us poor Londoners of our short leases, and procure us a decent material to build with, and architects to design our rural dwellings. It is bad enough to have *all compo and no architect* for our street edifices; but to put up with the prescription in the lovely village scenery about Middlesex, Kent, and Surrey, is hard for flesh and blood to endure! It is at least so to those who know that, to find good English architecture a man must not confine his researches to the Metropolis, and its lovely, picturesque, suburban neighbourhood. There is nothing about Manchester to vie with the banks of the Thames; but Bowden and Alderley, in Cheshire, afford the citizens a tolerable substitute for the Cockney's Richmond Hill: Alderley just now being the more favourite spot. It lies on the main line of the North-Western Railway. We would advise the architectural tourist to make a few hours' stay there, ascend the hill to Alderley Edge, and make an inspection of the villa residences upon it. Some of these, designed by Mr. Crowther, of Manchester, will realise the justice of our comparisons between town and country housebuilding. We were particularly pleased with a large villa designed by the architect just mentioned, who has very successfully adopted the expedient of wholly facing the outer walls with header bricks. The material employed is the local red brick, the ends of which, being better burned than the sides, have a pink, or rather reddish grey tone, which harmonises well with the dark brown roof tiles, and the redundant foliage of the surrounding ornamental grounds. Here too are some well-designed residences, wholly faced with ashlar; and everywhere one sees good sightly masonry employed in terrace walls, fences, gate piers, &c. "Mr. Compo" has happily no footing at Alderley Edge. Before quitting Alderley we should mention the large church and schools, built also under Mr.

Crowther's direction; and the Wesleyan Chapel, under that of Messrs. Hayley and Son, of Manchester. The church is a middle pointed edifice, very correct in an ecclesiological sense, and composed strictly *en règle* with those antique details its architect has so laudibly studied. It is, however, an early work of his; and, though a fine church, not equal to others he has since built in and about Manchester. The Wesleyan Chapel (or "church") is a remarkably fine edifice, built wholly of stone, on an elevated site, with nave, transepts and quasi-chancel, with its windows all filled with painted glass, and having a clock-tower and spire some 120 feet high. The style of architecture is decorated Gothic, and the structure, which is said to have necessitated the capping of the before mentioned Anglican edifice with its long desiderated spire, does great gredit to the liberality of the Wesleyan body.

We will conclude this article with some notice of the recently built places of worship in and about Manchester. They form a remarkable feature of the city, and give unmistakable evidence of the devotion and liberality of its citizens of every creed. Whether Manchester is or not a very religious city, we can not undertake to say; one thing is certain, that if the possession of numerous costly churches and chapels is to afford one a criterion for judgment, then is Manchester an essentially religious city. Spires and towers start up everywhere, and everywhere divide with the tall factory chimneys the task of cutting the horizon.

The churches devoted to the services of the wealthy Established Church naturally claim pre-eminence; but in Manchester the members of this body as a whole have exhibited little fervour in late church building, compared with what is observable of the Catholic and Dissenting communions of the city. The three best modern churches in Manchester are respectively the gift, not of the Anglican body, but of three rich benefactors, Lord Egerton of Tatton, Miss Atherton and Mr. Birley. Trinity Church in the Stretford-road, the earliest built of these three, is one of Mr. Gilbert Scott's, (or Scott and Moffatt's) works: a large Early English church, with a massive tower. It is a well arranged edifice, with an effective interior, the details somewhat heavy; and is remarkable as being one of the first churches built since the great ecclesiological revival in which the apse, now so common a feature of church building, has been substituted for the more usual—and more English—quadrangular chancel. Not far from this church, erected at the sole expense of Miss Atherton, stands another of the three edifices named, St. Philip's Church, erected at the expense of Mr. Birley, from the designs of Mr. Shellard, architect, of Manchester. This edifice has been placed purposely in the midst of one of the poorest districts, inhabited by the factory workpeople; and embodies the munificent effort of its founder to bring the services of the Established Church, made replete with every possible appliance of art, to the poor man's door. It is a large structure, designed in the Decorated style of Gothic architecture, and consists of a nave and spacious chancel, each with aisles, and a large tower (containing a peal of bells with chimes) crowned with a lofty spire: this last feature somewhat too lofty for the tower beneath it. The architect would have done well had he carried up his tower a little higher before introducing the bell-chamber; for, as erected, the effect is a little squat and ill proportioned. Some of the external features of this costly church, as the buttresses and parapets, have a weak and bald effect. The window tracery is of the kind termed Geometric, and many of the large handsome windows are very creditably designed. These, when we enter the interior, a very effective one, are found to be all filled with painted glass of a very costly description, the subjects being illustrative of Scripture history; but the mode of treatment, as it struck us, very unusual, and the general effect sombre and repulsive. Each window contains a picture in itself; the groups spread from side to side, regardless of the intervening mullions: and there seems to have been too great an ambition on the part of the artist to emulate the mere natural depicting of objects, with their shades, shadows, and other accessories, hardly suited to the translucent material he was called on to embellish. Doubtless the founder's intentions were excellent; and this poor man's church was meant to serve as a Scripture picture gallery. It is an edifice that forcibly suggests the propriety of devoting the internal wall-space of our modern churches to the introduction of paintings in fresco and mosaic.

But by far the finest of all the Anglican churches is that of St. Mary, Moss-side, erected by Mr. Crowther, at the cost of Lord Egerton, of Tatton. This again is a "Geometric Decorated" edifice, with nave and nave-aisles, chancel and aisles, tower, and spire, whose altitude to the top of the weather vane is some 242 feet. It has, for a modern church, the rare peculiarity of a high clerestory over the chancel as well as the nave. We have heard it objected to this fine edifice, that it is wholly a revival of the antique in detail; and certainly we do recognise, in nearly every feature, some well-known window or other part, that reminds us of the published illustrations of ancient churches; but we are by no means tempted to look upon the fact as an unmitigated evil. If it be true that every feature of this beautiful structure has its mediæval prototype, we can only say, the examples selected for imitation show the good taste of its architect; and the accuracy and spirit with which they have been rendered by one, who is well-known to have acquired a most intimate knowledge of our old English churches, fully compensates for the lack of originality that has been complained of. The adjoining parsonage and schools are very well grouped together, indicating no oddity, indeed, on the part of their architect, but enough of originality to show that, while his church proper has little of the *sui generis* about it, its architect was most probably restrained from the usual amount of self-glorification by a laudable humility, based on what might well be in him an intense appreciation of the perfection of ancient detail; and hence the people of Manchester have become possessed of one of the finest and most faultless modern churches in England. This church has a large and massive rood-screen of oak, with a pinnacled stair turret at each of its extremities, leading to the roofs of the aisles and clerestory.

St. Alban's church, in Waterloo-road, Strangeways, is another fine large church by the same architect. It stands on a most effective site, raised considerably above the roadway. The style again is "Geometric Decorated," the church consisting of nave with aisles on each side, bold south porch, and apsidal chancel, with tower on its epistle side, communicating with the chancel and south aisle by open arches. The nave and aisles are parted by cylindrical piers, sustaining an arcade and lofty clerestory, carried past the tower, and extending over the chancel, as at St. Mary's. This arrangement, common enough in ancient churches, and too seldom resorted to in modern ones, imparts an aspect of great magnitude and sublimity to the interior. The church was not completed when we visited it; but it bids fair to be a very fine work indeed.

St. Stephen's church, Greenheys, is an incomplete edifice, built in the more developed style of "Decorated" Gothic architecture, from the designs of Mr. Shellard, before named as the architect of St. Philip's church. The site is somewhat restricted; but the edifice itself is well designed, and of particularly pleasing proportions. It consists of nave, aisles, and chancel with aisles or side chapels, and a western tower of which only the lower part has been completed. The side of this church abuts immediately upon the street, from which it is entered by a very elegant doorway, with ball flowers and crocketted canopy, the labels terminating with nicely carved angel bosses, whence proceeds a moulded string-course, continued all along the side walls; and upon it rest the well-designed aisle windows, the whole effect being simple and graceful. The window tracery throughout is exceedingly effective; and the whole edifice, albeit a very unpretentious one, gives token of far more power than its architect has displayed in his larger church of St. Philip's, Hulme, before described. Here for the present we must break off; and in our next speak of the other new churches and chapels of Manchester.

THE FIELD BOILER, ITS PRINCIPLE, CONSTRUCTION, AND ACTION.

By Francis Wise, C.E., M. Inst. E.S., &c.

(*With an Engraving.*)

The object of what is commonly known as a steam boiler, is to impart the heat evolved by the combustion of any suitable fuel, to water contained in a close vessel, in such manner as that evaporation may ensue, and that the vapour given off may be employed as a source of power or for other purposes; and further it must be admitted that, other things being equal, the less time and space occupied in evaporating any given quantity of water the better. It is evident, however, that if increased rapidity of evaporation is to be achieved at the cost of economy in fuel, of space, or of safety, the advantages of quick evaporation will be either neutralised or diminished.

In the Cornish and other boilers of that class, the heat generated in the furnace is not absorbed with sufficient rapidity by the water to render quick combustion economical, inasmuch as with it a considerable proportion of the heat evolved by the burning fuel, instead of being taken up by the water, is either absorbed by the brickwork of the flues, or passes away uselessly by the chimney. The reason, therefore, of the superior economy of slow combustion in Cornish boilers is, that they require a considerable time to take up a fair per-centage of the heat generated, and that unless sufficient time is allowed them for doing so, a certain proportion of the heat is wasted, which indeed simply amounts to saying that the Cornish boiler is imperfect in principle (insomuch as, beyond a comparatively low limit, it is incapable of utilising a proper proportion of the heat capable of being generated in its furnace) and does not in any way go to show that, with a boiler capable of rapid absorption, slow combustion is either advantageous or desirable. At all events it is obvious that, if by using an improved construction of boiler, we can evaporate the same amount of water as is evaporated by the best Cornish boilers, with greater safety and at least equal economy of fuel, in a space of about one-sixth of what is necessary under the Cornish system, there is a clear gain, of much importance; and if to this can be added greatly increased* accessibility and non-liability to wear and tear in the body of the boiler, we shall have made a decided and highly important step in advance.

How, then, is this to be done? It is clear that anything approaching to the Cornish system, with its long and partly useless flues and large body of sluggishly circulating water, is out of the question. Turning, then, to multitubular boilers, in which the heated products of combustion are conveyed from the furnace to the chimney, by a number of small tubes passing through the water-space and intended to impart heat to the water, and what do we find to be the result? Why, that flame entering the tubes is almost immediately extinguished, through want of a proper supply of oxygen, and that the heated products of combustion, to a great extent, pass through the tubes without their heat having been absorbed by the water surrounding them, and that the more rapid the combustion, the greater (owing to the imperfect circulation) is the proportionate loss of heat. This, then, in its present form, is evidently not the system whereby the end desired is to be achieved.

If these premises be correct, two things are clear—viz. firstly, that we cannot use the Cornish system with its large body of inert water; and secondly, that the plan of passing the heated products of combustion in thread-like streams through the water space, as in the ordinary multitubular boiler, is also practically incorrect.

Let us now suppose that, instead of passing the products of combustion in small streams through the water, we cause the water itself to pass in like streams (and with a rapidity of flow self-proportioned to the heat whereby it is surrounded) into aud through the hottest part of the furnace. The result will then be that, with slow combustion the circulation will be slow, so that the quantity of water presented to the action of the fire in any given time will be exactly suited to its heat-imparting power; and that if the rapidity and intensity of the combustion be increased, the rapidity with which the water will pass through the furnace will be proportionately increased, and this will be so even although the fire be urged to give out the greatest possible amount of heat. Hence it is evident that, as the velocity of the circulation is in all cases regulated by the heat-giving power for the time being of the furnace, it matters not whether the combustion be slow or quick, excepting that in the latter case we shall be enabled, by the greater velocity with which the streams of water pass through the furnace, to evaporate a proportionately greater quantity in the same space. Now this is precisely the principle of the boiler under notice, the practical results of which entirely corroborate the foregoing remarks, and satisfactorily prove that the principle of submitting the water, in small and rapidly circulating streams, to the most intense heat of the furnace, is the true one, and superior to any other yet introduced; as also that, in this way, almost the whole of the heat generated in the furnace (with the exception of what is necessarily employed for the purpose of maintaining a sufficient draught) may be utilised in the production of steam, and that economy of space and weight may thus be made to go hand in hand with that of fuel.

A consideration of the construction of the Field Boiler will at once show how these effects are produced, while the boiler itself is at the same time rendered safer than any other kind of boiler in existence. It should however be firstly mentioned, that the principle of construction adopted in the Field boiler is not only applicable to boilers for stationary purposes, but also with equal advantage to those of the marine and portable classes, and with reference to the latter class, has proved itself capable of going through the most severe work uninjured, under which other boilers have required constant repair, and have never, at the best, been free from leakage. The construction of the Field boiler is this:—

It consists of two principal parts, namely, the water and steam space, or body of the boiler, and the furnace, or chamber wherein the fuel is burnt. For stationary purposes the boiler is made cylindrical in form, with an annular water-space *a*, surrounding the furnace *b*, as shown in Fig. 1, of the accompanying Plate 14, but the form may be readily varied and adapted as required to suit any peculiarities of circumstance or position, whether for land or marine purposes. In the case of the cylindrical vertical boiler referred to, a number of tubes *c*, placed annularly around a flue tube *d*, passing upward through the boiler, hang down or are pendant from the under-side of the water and steam space *e*, into the furnace *b*.

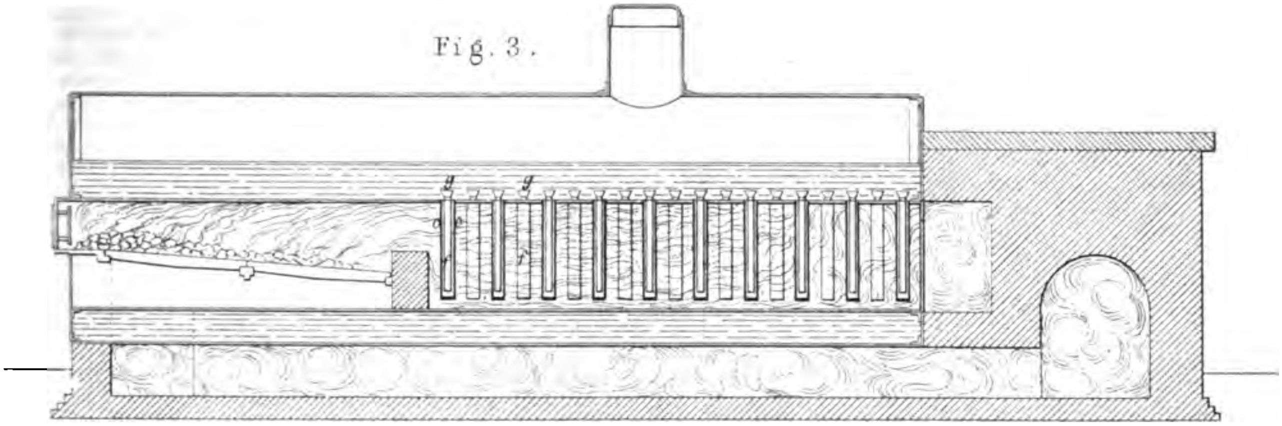
These tubes are open at their upper ends into the water-space, and being closed at their lower ends are consequently (when the boiler is in readiness for starting) entirely filled with water, the top level of which is some inches above their upper ends. Within each of these tubes is freely suspended, by means of feathers *x*, a smaller tube *f*, open at both ends, the upper end of which rises above the level of the upper end of the outer tube *c*, but is short of reaching to the bottom of it. The tops of these inner tubes are provided with trumpet or funnel shaped mouths or deflectors *g*, which as will be seen perform an important part in the action of the boiler. A baffle-plate or cylinder *h*, suspended beneath the opening into the flue tube *d*, which passes upwards through the boiler, prevents any portion of the heat of the furnace from passing away without having firstly enveloped and become almost entirely absorbed by the pendant tubes and the water circulating within them.

Boilers upon this principle are peculiarly adapted for marine purposes, insomuch as not only is the body of water which they contain, and which is liable to surge from side to side by the roll of a vessel, considerably less than in boilers of the ordinary construction, but it has been found that they may be worked with water completely saturated with salt. Indeed, experiments which have been made show that even with a super-saturated solution, that is to say, a solution which after saturation has been further evaporated until a considerable portion of salt is held only in mechanical suspension, the tubes work well, and will, on the re-lighting of the fire, absolutely eject the salt which has settled in them during a period of rest, even although its depth may be sufficient to cover the bottoms of the inner tubes. A boiler of this kind is shown in Fig. 2, in which *b* is the furnace, the flame and heated gases from which, after passing the bridge *q*, continue onward among a series of pendant double tubes, and returning along a flue—also containing pendant double tubes—towards the front of the boiler, pass away by the uptake *d*. The double tubes thus arranged, and not too closely packed, permit the flame of the furnace to play among them for a considerable distance without extinction; and by the position of the surface they present to the flame and heated gases are most effective in their economical results. This was curiously shown in the case of a Cornish boiler, to which a few of the double tubes were applied in the main flue, immediately behind the bridge, in the manner shown at Fig. 3. In this case the amount of heating surface added to the boiler was 10 per cent., but the saving of fuel, instead of being in the same proportion, was more than 20 per cent.; and it was found in this case, when there was only a thickness of about ⅜-inch of iron in which to fix the tubes—as had previously been found with boilers having tube-plates of greater thickness specially intended to receive and support the double tubes—that such was their perfect freedom of expansion and contraction, that there was not a drop of leakage.

It will thus be seen that this system, in addition to its other advantages, does away with that serious and inevitable defect of tubes fixed at both ends, namely, leakage; the destructive effects of

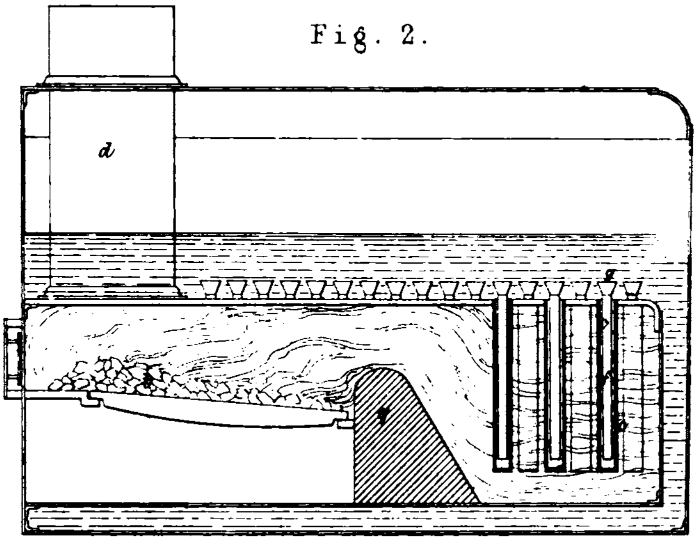
THE "FIELD" STEAM BOILER

Fig. 3.



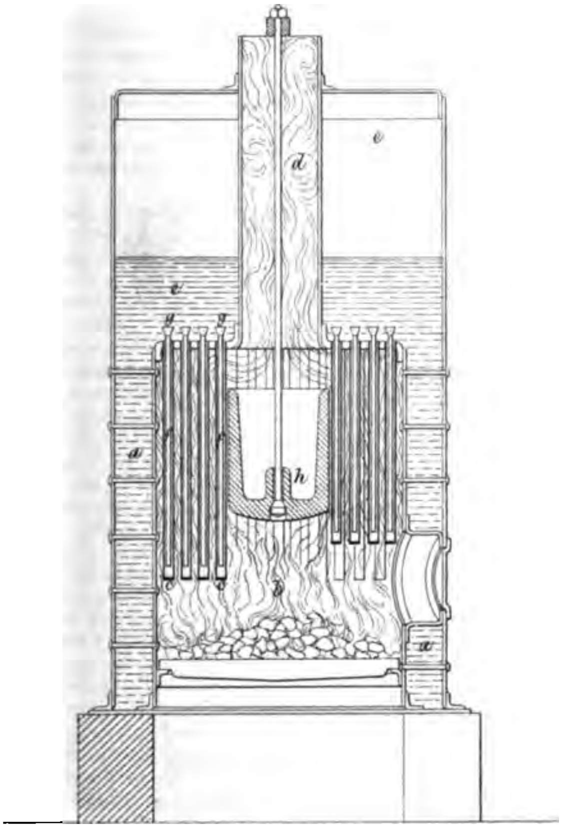
Cornish Boiler with Field's Tubes

Fig. 2.



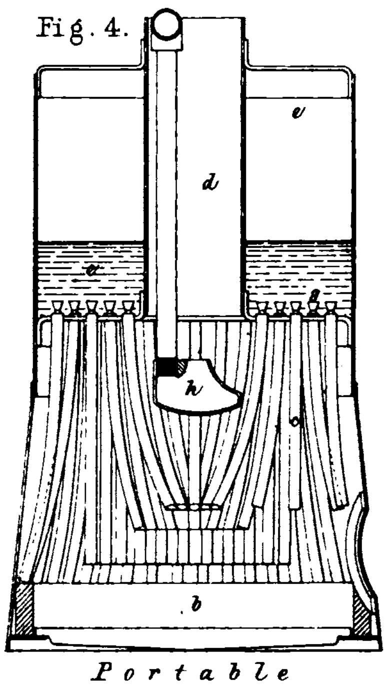
Marine

Fig. 1.



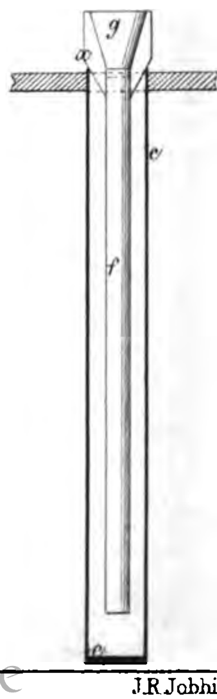
Stationary

Fig. 4.



Portable

Enlarged View of the Tubes c & f.



F. Wise, del[t]. J.R Jobbins

which are well known to every person who has paid any attention to the working of boilers; and further, the same feature which does away with the very serious evil referred to, has an important effect in lessening the first cost of the boiler, insomuch as it enables the tubes to be securely and perfectly fixed, simply by a very slight expansion of their upper ends, without the use of any ferules or other objectionable arrangement. To fix the tubes all that is necessary is to make the holes in the tube-plate slighly conical, their diameters at the lower surface of the plate being equal to those of the tubes, and their upper diameters somewhat larger, and then after having slightly expanded the upper end of the tube, to place it in its intended position, and by means of one or two blows with a hammer upon a steel conical mandrel inserted in its upper end, to farther expand the tube, so that it may fill and jam itself in the hole in the plate.

The facility with which a tube may thus be fixed is a matter of great importance in case of injury occurring to a tube during the working of the boiler, as at the worst it involves only a trifling delay before the damaged tube can be replaced and the boiler again put in perfect working order, without its being necessary even to call in the assistance of a skilled workman, a class of individuals generally found to be unobtainable at the very time when most urgently wanted.

The boilers for stationary purposes as already described, though calculated for steady and continuous working, and economical in consumption of fuel, are not at the same time so heavy or cumbrous as to preclude their being used with advantage for various descriptions of portable engines, as in point of fact they are lighter than those ordinarily used for such purposes; and where extreme lightness is not of paramount importance are certainly the most desirable form of boiler to employ. There are cases, however, and that of steam fire-engines is one of them, in which extreme lightness and portability in the boiler, combined with a power of raising steam with great rapidity, are of more importance than economy in fuel. In such cases it is obvious that the weight of the water casing and of the water contained in it, would constitute a comparatively serious objection to the employment of the water-cased boiler, which would be also further objectionable on account of the extra time required to heat the additional quantity of water contained in the casing. For purposes, therefore, of the kind referred to, the boiler used is of the type represented at Fig. 4, in which the water casing is entirely dispensed with, and the tubes used—which are of smaller diameter than those used in the other types—are so arranged as that the lower ends of the outer circles constitute an almost continuous casing around the fire-grate.

In working these boilers, a steam jet is used as soon as steam appears, for the purpose of urging the draught, and is continued in action until the engine is started, when the jet is shut off and the draught is maintained by the exhaust steam which passes by the pipe into and through the hollow baffle, whence it issues into the chimney. These boilers were designed for and are used with the greatest success in the steam fire-engines manufactured by Messrs. Merryweather & Sons, whose small class engines, weighing in all about 30 cwt., raise steam from water, which at starting may be little above freezing, to a pressure of 100 lb. on the square inch in 9½ minutes, and maintain the pressure undiminished while doing absolute work, in raising water to the extent of over twenty horses power. The engine Sutherland, which weighs complete only 2 tons 18 cwt., is fitted with a boiler of the same class, and has shown wonderful rapidity in raising and generating steam. Thus, at the Crystal Palace, this engine raised steam from cold water to a pressure of 100 lb. on the square inch in ten minutes, and subsequently threw a jet from a 1⅝-inch nozzle vertically to a height of 200 feet, and maintained it steadily up to a height of more than 180 feet, for over five-and-twenty minutes, showing itself capable of continuing to do the same for any length of time desired. The boilers of the first-named class of engine are 2 ft. 3 in. in diameter and inclusive of furnace are only 4 ft. 6 in. high, while that of the latter is 3 ft. 6 in. diameter, and 4 ft 6 in. high. In order to obtain the required large amount of steam from boilers of such disproportionately small dimensions as these, it is obviously necessary that the heat of the furnace be of the most intense character, and it is equally obvious that, in order to maintain it at that intensity, a very large supply of air must be drawn through the burning fuel, and as this can only be done by means of a proportionately fierce draught, it naturally follows that a considerable per-centage of heat is wasted; not, indeed, by reason of any deficiency of absorbing power in the boiler, but on account of the disproportionate strength of draught required to draw the necessary amount of air through the furnace; and which, consequently, not only compels the rapid rush of too large a proportion of the heated gases up the chimney, but also, at the same time, carries with them a by no means insignificant amount of the burning fuel itself. Yet notwithstanding the disadvantages under which they thus necessarily labour, and which are, in their nature, so inimical to economy in fuel, the workings of these boilers show results quite equal to those of the majority of ordinary stationary boilers, and therefore form another convincing proof, if any were required, of the correctness of the principle upon which their construction is based.

A consideration of what takes place in the working of the Field boiler will at once clearly show why it should, in all cases, contrast favourably with other boilers employed under similar circumstances. Thus, taking for example the size of stationary boiler known as 80-horse, but which will, in reality, work with ease up to 120 horse-power, the outer diameter of this boiler is 6 ft. 6 in., and its height 8 ft. 8 in. It contains 490 square feet of tube surface, the outer tubes being 2 inches in internal and 2¼ inches in external diameter; and the inner 1 inch in diameter. Now, upon lighting the fire the water in these tubes immediately commences to circulate every increment of heat, however trifling, added to the water contained in the annular spaces, between the inner and outer tubes, lessening its specific gravity, and causing it to ascend, and cold water to consequently descend the inner tubes to supply its place. This action goes on increasing gradually in rapidity until ebullition commences, at which time the velocity of flow is increased enormously, owing to the great difference between the specific gravity of the mixed water and steam ascending in the annular spaces, and that of the solid water descending the inner tubes.

Taking the velocity of flow down the inner tubes at 10 feet per second, and the number of tubes at 289, we shall have a quantity of water equal to about 96 gallons passing down into the furnace, and being submitted to its most intense action in every second of time. Moreover, owing to the principle of action of the tubes, the water so submitted necessarily belongs to the less heated portion of the contents of the boiler, and consequently possesses the greatest capacity for heat. Now when we consider that an amount of water equal to the entire average contents of the boiler is thus passed into the furnace, with the intervention of only one-eighth of an inch of metal between itself and the fire, in every six seconds of time, some idea may be formed of the immense rapidity with which the heat of the furnace may be passed into the water; which may be further strengthened by reflection on the well known fact, that if it be attempted to harden a tolerably large piece of steel by plunging it when hot vertically into cold water, and holding it motionless in that position, the attempt will prove a failure, inasmuch as the water will fail to carry off the heat from the steel with sufficient rapidity to effect the hardening, but if instead of holding the steel motionless as described, we move it more or less rapidly from side to side through the water, the hardening will be at once effected. Now, this is precisely the difference between the ordinary kinds of boiler and the one which forms the subject of this paper. In each case we have on the one hand a mass of water subjected to heat, and unable to change its position with sufficient rapidity to absorb the heat presented to it; and on the other, a constantly changing surface of fluid, carrying off the heat from the metal with great rapidity, and in each case effecting the object desired.

Here, then, is one very obvious reason for the economical results achieved by these boilers, even under circumstances which might seem to put economy out of the question, the fact simply being that, in ordinary boilers, the circulation, left to shift for itself, has great difficulty in becoming of a decided character in any direction, so that the water instead of taking off, or as it may be expressed, rushing off with the heat from the metal as required, hangs about it, and with comparative slowness conducts it away. The consequence is that much of the heat passes into, and away by, the flues instead of into the water, and thus it is, as was before remarked, that slow combustion with ordinary boilers necessarily shows to better advantage than quick. It is important in discussing the merits of any boiler to advert to the difficulties, if any, likely to arise from the deposit on its surface of these troublesome matters, the sulphates and carbonates of lime or such other compounds of them as are usually thrown down in the form of a hard scaly incrustation. It is well known that such deposits are encouraged by sluggish circulation, and that where the circulation is most feeble, as well as in the neighbourhood of the feed pipe where the water first enters the boiler, the deposit is usually thicker than at any other places. Bearing this in view, we are naturally led to expect that the effect of very rapid and constant circulation will be to prevent deposit in the channels wherein such circulation takes place, and are therefore scarcely surprised to find that the tubes of boilers of steam fire engines constructed upon the Field principle, and worked almost daily for two years, have remained entirely free from deposit.

It may be that some small part of this remarkable result is due to the continual changes of water, with which, from the nature of their duties, these boilers are worked, but assuredly, if that be so, the part borne by these changes in preventing incrustation is very small indeed. But allowing that continual change of water has some appreciable influence in the matter, stationary boilers on the Field system now at work show that with the most ordinary precautions there is practically no incrustation. The writer was present lately at the opening of one of these boilers for the usual quarterly examination, and is enabled to state that there was no hard or scaly deposit whatever. At the bottom of the water-space there was a light coloured mud, which, when dried, proved to be an impalpable powder, consisting doubtless of the matters which, in ordinary cases, are deposited in boilers in the form of hard incrustation, but which, in this case, had been kept in mechanical suspension until finally thrown down into the water-space as described. The precautions which had been taken in this instance, and which were so thoroughly efficient, were of the most simple character, and consisted, firstly, in the employment of an inexpensive water-heater, whereby some of the calcareous matters contained in the water were thrown down previous to its entrance into the boiler, and secondly, in the use in the water of a trifling quantity of composition, known as Buck's, and consisting, apparently, chiefly of soda, which seemingly had the effect of completing whatever was left undone by the heater.

These facts dispose of the only point suggested by practical men as likely to prove a source of difficulty with the Field boiler; and leave its important advantages of economy in fuel and of space, ease in firing, accessibility for examination and repair, and perfect safety, without any corresponding drawback.

BUILDING MATERIALS, PATENTS, &c., AT THE ARCHITECTURAL EXHIBITION.

Inasmuch as most of the staple contents of the exhibition remain as heretofore, some of them through successive seasons, there is little occasion now to recapitulate the opinions we have expressed regarding them from time to time. But it is very noticeable how the influence of a better taste has found its way in almost every direction in which art is concerned, so that our simplest vane-terminals and earthenware ridge-tiles have now stamped upon them a degree of character, which till lately they were not wont to assume, more in accordance both with variety, according to their position, and of design, according to the special requirements of different styles. Of old exhibitors who still retain their "space," the latter being more or less changed in appearance, we may note, in metal work, Messrs. Peard and Jackson, Messrs. Hart and Son, the Vieille Montagne Company, Messrs. Hobbs and Co., and Messrs. Bond and Scammel; besides some ingenious Window Casements in wrought-iron, adapted either to stone or wood mullions, and which have also the recommendation of being cheap as well as durable. The price of these casements, without frame, begins at twenty-three shillings, and they can be made to any size to order. The contrivance for the fastening and the stay bar are so simple as not to be liable to disarrangement. The makers are Messrs. Gibbons and White, 345, Oxford-street. There is also a large show of Messrs. Thompson and Co.'s patent electric bells, electric fire alarms, and alarms for windows and doors, which are found a great acquisition as articles of domestic use. Messrs. Baugh and Co., too, merit a word of approval, in passing, for their "specimens of enamelled iron," a material which appears to be capable of still more extensive application.

Mr. Rosher's "Architectural Decorations," in artificial stone, are prepared with an indurating solution, by the use of which in the manufacture greater durability and a better surface is obtainable. Still, as we believe necessarily happens in every case, the process of induration changes, not merely the appearance of the surface of the stone as regards texture—so to speak—but also the absolute colour of the original material, rendering its effect much darker and duller than when in its original state. The Fern Brick, for ferneries and walls of conservatories, is a suitable and useful manufacture. The material being porous is fitted for the cultivation of these plants; and, the shells being loose, the ferns are easily removable to other parts of the fernery without disturbing their roots. Similar recommendations attend the introduction of the (Foxley's patent) "Garden wall bricks," supplied by the same firm. These bricks are manufactured with a perforated bead on the edge, so that in training fruit trees trellis work is unnecessary, which invariably accumulates insects and dust; while nailing, too, is rendered needless, which, besides defacing the walls themselves, has a tendency to injure the tender branches of trees, and by confining them too close to the wall, it frequently interferes with their growth, as also that of the fruit.

In (20) we observe some praiseworthy contributions from Mr. Colton, of Robert-street, Hampstead-road. They comprise a series of Arabesque decorations for the walls of drawing-rooms, &c., and some emblematical subjects of the International Exhibition, 1862, for which they were prepared, and to which the Painters' Company of the City of London awarded a first-class silver medal. If there is one greater drawback to them than another, it is the style of ornament selected, viz., that of the time of Louis XIV. Mr. D. O. Boyd's Patent Flue Plates, for dividing the vitiated air-flue from the smoke-flue, have previously come under our notice, as a useful invention for obtaining for each room effective ventilation by a separate and highly rarefied air channel. To this is now added his "Hygiastic Warm Air Stove, and Hygiastic Fire Grate," made under the direction of the architect, Mr. F. P. Cockerell, for the grand staircase, corridor, lodge, and other rooms at the New Freemason's Hall, in progress of erection in Great Queen-street, London.

Mr. W. Godwin, of Lugwardine, near Hereford, still distinguishes himself for his persevering experiments in pottery manufacture, and especially in Encaustic Tiles. Some of the latter, treated in the broadly-rough, but effective style of ancient patterns, may be cited as a near approach to the originals themselves. This success is greatly owing to the opportunity afforded to Mr. Godwin in scrutinising the manufacture of the old tiles in the Cathedral of Hereford, when reproducing the majority of the patterns for their extensive use in repaving the whole of the portions of the fabric recently restored. Messrs. Maw and Co. retain their show space, as does also Mr. England, but with no very noticeable change in the specimens exhibited. The moulded bricks and tiles manufactured by Messrs. R. and N. Norman (5), and similar articles by Mr. Cooper (6), are among the best of their kind. The latter especially display a great advancement as regards their appearance and design, while in a practical point of view much can be urged in favour of his "Ridge Crests." These are stated to be made of superior clay, subjected to a great pressure, and being in one piece only, the patterns cannot be displaced, as is often the case with grooved tiles, nor does the frost, however severe, affect them. Mr. G. Jennings, as usual, exhibits a multifarious series of his inventions, which are chiefly of the sanitary kind, deservedly known and patronised; too much so to require a detailed description here. In perfecting some of these he has been fortunate enough to secure the able assistance of an experienced engineer, Mr. S. E. Rosser, of Dorset-street, Fleet-street. As a substitute for paint, Stephens' "Stains for Wood" are an admirable medium, having the recommendations of economy, durability, and beauty of effect. The natural grain of wood may be imitated by art, but the most successful imitation has a sameness of appearance when compared with that continual variety which different woods present in their natural grain. The advantage of using the above stains is this, that this natural grain is not obscured, but shows through more beautifully under the rich tints which are given to it by them.

On the whole, this department of the exhibition maintains its position hitherto, but much remains to be done before it can be considered as properly representing either the inventive productions or the exigencies of this *working* age.

ON THE ART OF LAYING SUBMARINE CABLES FROM SHIPS.*

By Captain Jasper Selwyn, R.N.

A renewed attempt is about to be made to connect by a submarine and electric wire the intelligences and interests of the old world with those of the new, and no enterprise of this age promises so much benefit to the human race as the realisation of such a method of instantaneous communication. The subject, therefore, may fairly be considered as one well fitted to interest the members of a society devoted to the cultivation of the arts—the highest art being that which is calculated to benefit mankind; while on the other hand, by no other body could the views for which a hearing is sought be more fitly stamped as current coin or repudiated as base metal. But that I am aided by the observations of some of the first mathematicians and the most celebrated engineers of this or any other country—if I had not secured the direct support of many of the most distinguished members of my own naval service—I should scarcely have dared to advance here what might be stigmatised as crude opinions or ill-considered theories. Yet I feel that I must ask your indulgence if, while asserting some things with the enthusiastic feeling which must animate every officer of my profession who thinks he may perchance contribute something, however small, to the solution of a great nautical problem, I should fail adequately to explain, in all cases, points where the apparently intuitive knowledge of a seaman leads him confidently to predict results for which to the landsman's mind there seems no sufficient cause.

It will be readily conceded that, just as no railway could be constructed with any chance of economy or ultimate success, unless after the most careful surveys and calculations—as again, any fundamental error in such calculations would deserve the most careful elimination—so in this great work of laying an Atlantic telegraph cable, which is immeasurably more difficult, it behoves us to examine and re-examine the bases on which we are to proceed, and to refuse attention to no suggestion, from whatever quarter it may come, until we are absolutely convinced of its worthlessness.

Among those considerations which, as I hope to show, may most favourably or most fatally influence the success of the delicate operation of laying a comparative thread of electric communication across the Atlantic, the curves described by the cable in sinking may claim the very foremost place. The question first to be solved is—is the path of the cable during its descent to its ocean bed a straight line, an upward, or a downward curve? Is it an inclin d plane? Is it a parabola with a small curve of contrary flexure? Is it, or when is it, a catenarian curve?

As no less an authority than Professor Airy has held and published the last-mentioned opinion, I will, if you please, consider that case first. A ship at rest in an ocean of 2 miles in depth, allows a sounding line, carrying an iron weight of 96 lb., to run freely to the bottom. By many and accurately made experiments we find its time of descent to be fifty minutes nearly. We may treat it roughly, for our present purposes, as 2 nautical miles per hour. Now we can by no means expect that any telegraph cable, more especially the present Atlantic (a specimen of which was exhibited), could sink at a materially greater rate. More probably it would be considerably longer in reaching the bottom. But we will assume that it sinks as fast. Then, in one hour, a cable which is being paid out without strain, will reach the bottom in 2 miles depth of water. If during that hour the ship has made a progress of only 1 mile, and the natural acceleration of the descending cable has not been interfered with by brakes, the curve described will inevitably be a catenarian one; and this will be the case whenever, no strain being kept on by mechanical appliances, the rate of sinking of the cable is in excess of the rate of progress of the ship. It is always thus in shallow water with heavy cables; a catenarian curve is there the invariable rule.

Next we will consider under what circumstances the cable will pursue a straight path, on an inclined plane, to the bottom. If the rate of sinking of the cable be again assumed as 2 miles per hour, and any rate of speed be given to the ship less than or equal to this, while a strain by brakes is placed on the issuing cable sufficient to prevent acceleration beyond the speed at which it is dragged out of the ship, then the line of descent will be a straight one, or little varying from an inclined plane. But in both these cases we have assumed a speed of ship of 2 miles only per hour, which in practice would be inadmissible.

We will now pass on to the case in which, as always really occurs in practice, the speed of the ship is materially greater than the rate of sinking of the cable. The cable issues from the ship, still under some strain, at from 20 to 30 per cent. in excess of her speed, which we will call 5 miles in the hour. That is, in one hour the ship has passed over 5 miles of ground, 2 miles of the cable has sunk, and, say 6 miles of it has been paid out, or has issued from the stern of the ship. What has become of this? and in what curve, or on what inclined plane, is it now arranged? This so far, is the real point at issue. I venture to hold that the curvature which under these circumstances takes place is an upward one, of the nature of a parabola, having a small curve of contrary flexure near the bottom, the general convexity being towards the surface. My reasons for this opinion are as follows:—First, whatever may be the speed of the ship, the rate of sinking of the cable can never be increased correspondingly, or indeed in any degree. Secondly, the slack paid out, averaging 25 per cent., is very much more than the difference between the horizontal distance, 5 miles made good in one hour, and the diagonal distance from the surface to the bottom on the same route. And this excess will certainly not be expended in producing a serpentime form, for which there is no possible cause, unless a very large proportion of slack is paid out, but in that upward curve, the cause for which is to be found in the resistance to cutting descent of the fluid through which the cable is moving. The less the specific gravity of the cable, and the larger its diameter, the longer will be the comparatively straight part of the parabola, and consequently the more cable will be exposed to the effect of lateral surface currents, wherever such exist. Indeed, a valid proof that there is a considerable portion of the cable so exposed to currents, and therefore that there is such an upward curve, is to be found in the fact that on several occasions the issuing cable was run away with by a comparatively trifling current, making it take an angle with the ship's course. This could not have been the case, had only the small portion of cablo been exposed to the effects of currents which would be due to the cable following an inclined plane between the ship and the bottom. This upward curve would also be liable to be produced or increased when there existed a current in a direction opposed to that of the ship's progress, for thus there would be an increased resistance to cutting descent. While I thus attempt to show what is probably the curve taken by the cable, and what are the dangers attendant upon it, how it is produced, and what are its limits, I also wish to point out that, if this be the truth, there is an important advantage which may possibly be realised in case of a breakage of the cable. We all, I am sure, sincerely hope that this may not be the case, but should it occur, with proper apparatus attached to a strong hawser or line, and by steaming, so soon as the signal of rupture was heard, directly across the track previously followed by the cable-laying vessel—her consort, whose station should always be about 3 miles on the lee quarter, might catch the cable again before it was irreparably gone. I exhibit some apparatus for doing this automatically, and without such assistance; but there will be considerable difficulty in using it, unless by men of great nautical skill.

I propose now to consider the lateral curves, with their effects which may be made by the cable, owing to surface currents at an angle to the ship's course. If, the ship's course being west, a surface current be entered whose direction is southerly—*i.e.* towards south—no effect can be noticed on the ship herself until, by astronomical observation, the existence of such a current is evidenced in the difference between the true and dead reckoning position; but it is otherwise with the issuing cable. It may immediately be observed to have deviated from its former line straight astern, and is now carried at a greater or less angle on the port or left-hand quarter; also, the strain shown by the dynamometer and the rate of issue will rapidly increase. Now no more fatal error can be committed by the engineer than to load the breaks, and attempt to resist this. The only remedy is to go faster, steer a current course, and get out of the current as soon as possible, yielding so much to the increased demand for cable as never to bring more than a very small strain on. But it may be objected that, by so doing, an enormous percentage of

* Paper read before the Society of Arts.

slack will be lost. It is so apparently, but not really; for, as the current is but a surface disturbance, so soon as the cable in sinking has passed through it, the line in which it is laid follows really the true track of the ship as she is carried by the current, although, while in the current, it is carried in a loop far away to leeward. This it is very difficult to explain clearly without a diagram or model, to which I must therefore refer you; but it results from the fact that the cable exposes a very large surface to the lateral action, and is not like the ship forced against it by the motive power. If we conceive a fluid surface like oil floating on water of a certain depth—that this oil is carried laterally at a given rate by a cause which does not affect the water under it; if next we imagine a cord laid over the oil and sinking first through it and then through the water, we shall be able to understand how in the oil the cord may be carried off in a loop, or bight, as it is called by seamen, laterally, falling thereafter through the water in the true line in which it is laid. But, of course, this will only be the case where the current has no great depth, for if from top to bottom the whole body of water moved, there must be a uniform lateral curve, just as there is a vertical one owing to the resistance to cutting descent.

It will be useful to remember that the new Atlantic cable, having a diameter of one inch and a quarter, exposes about 633 feet of section per mile, and a two-knot current at 11·8 lb. per square foot brings a strain upon each mile exposed to it of over 3 tons. Now, as in yielding to the set of the current more and more cable will constantly be demanded, and therefore more will be exposed to it (the rate of sinking never being capable of increase), it would at first sight appear that this demand ought to be resisted; and in the first attempt at laying, there was an instance in which this course was pursued, which, as I should have expected, resulted in the breaking of the cable. I hope that so unwise a proceeding will not be repeated. It should be a rule with those who are laying deep-sea cables, that the maximum allowable strain must never exceed one-fourth of the breaking strain, even where the cable is made comparatively inextensible by the use of longitudinal fibre or wire; but where spirals of iron or steel wire enter into the construction of a telegraph cable, not being in contact with an incompressible core, then no strain sufficient to stretch the copper wire, which is now acknowledged not to be protected from such tension by any spirals—I say no strain, not even that due to its own weight in any great depth, can safely be borne by it. Again, the rule of the cable-maker ought to be that, his cable being hung freely in air, the weight is to be accurately observed which suffices, not to break it, but to stretch it 2 per cent., and on no account must more than a half of this be afterwards brought upon it.

If, after accurately calculating the number of pounds of copper per mile which will carry messages a certain distance at a certain remunerative rate, I then subject that wire to any tension which can decrease its area, and do so moreover, to an uncertain extent, at any place where the wire, although seven-stranded, happens to be unusually soft, I might as well not have calculated, for I cannot secure the result. Therefore, even one per cent. of stretching is to be avoided if possible. There is no other way of doing this than by adopting either straight steel wires, inclosed in an elastic compound, as in Mr. Mackintosh's cable, or less perfectly, but probably sufficiently near inextensibility, by the steel spiral in contact with the incompressible copper conductor of Mr. Allan.

The next branch of my subject to which I will beg your attention is the formation of kinks. The causes for their formation are various, the process of coiling and uncoiling being the first. The means of avoiding those so caused, while securing many other advantages, I have so often brought before the public that it would unnecessarily detain you if I were to do more than point out the model and diagrams of the floating cylinders which I have always consistently advocated. But there are other causes for kinks which might be avoided. No treatment could well be more unfavourable for a telegraph cable than that of forcing it to pass round comparatively small drums from 4 feet to 8 feet in diameter, as brakes under a heavy strain, and none could be found more certain to induce the formation of those kinks which are so much to be dreaded. Now, kinks thus formed may occur under water, after the cable has been lost to sight in the waves, and this will happen most often when the ship is pitching, and so suddenly slacking up the cable, which then not being able to sink faster than it did before—being, in partially waterborne—arranges itself into a curve such as it had when tightened round the drum. The next upward pitch produces a kink which may, if it does not break the cable, yet cause inside the elastic sheath solution of electrical continuity. This recovers itself temporarily at the end of an hour or so, when the strain is taken off by the approach of that part of the cable to the bottom and the ends of the broken copper wire come together again, only eventually to be destroyed by the accumulation of electrical resistance at that point.

Now this can be in part avoided by the use of an elastic connection for the retarding apparatus—I will not call it by the ill-omened name of brake—nor should it be in any way similar to those machines which have been hitherto used for such purposes; but rather like the human hand, with the difference that the rubbing surfaces must be rolling surfaces also. By such means there must be established a continual give and take of the cable whenever the ship is pitching heavily, as even the Great Eastern may do if she gets a sea on the quarter or bow. It should not be forgotten that the danger of bad weather will, in this instance, be double what it was in the Agamemnon's case, because the time occupied by one ship in laying must necessarily be twice as great as when two are employed, starting from the mid-Atlantic.

IRRIGATION WITH TOWN SEWAGE.

By George King.

(*Concluded from p.* 147.)

In 1860, seven acres out of the ten, detached from the remainder by a large house and grounds, were broken up and again planted with early potatoes, the remaining three acres being left for a third year's cropping. The part of the Old meadows nearest to Restabrig, part of the glebe land of South Leith, and along the back of the railway depot, the part leased by Mr. John Brown, had suffered severely from the frost, it was in a worse state than any of the Craigintinny meadows; this part lies much too flat, and requires reforming upon the best principles of the bed system, otherwise it will be always liable to injury from the same cause. There is no doubt but that the loss sustained by the reduced prices of those lots that year would have paid the cost of re-forming. The roup took place on the 30th April, two days after the Craigintinny roup. The part first rouped was that described as north side of the burn, and which is far the best part of the meadows. The twelve lots, which comprise the whole length this side of the burn, averaged over £40 per acre, one lot made £44 per acre. The part nearest Restabrig, where the lots were most injured by the frost, let at £19 5*s*., the lowest, but as the roup proceeded towards the opposite end of the meadows, the prices rose to £38 10*s*., the highest. The four lots of Italian rye grass reserved for a third year's cutting, were not quite so fine as the year before, but realised £30 per acre the lowest, and £35 15*s*., the highest. The average amount of roup may be made up as follows :—

No. of lots.	Description.	Quantities.			Average per acre.			Amounts.		
	Old Meadows.	A.	R.	P.	£	s.	d.	£	s.	d.
12	North of Burn ...	8	0	0	40	0	0	320	0	0
19	Remainder of lots	22	0	0	27	10	3	605	5	6
4	Italian rye grass —	3	0	0	31	16	0	95	8	0
45	Total	33	0	0	33	2	1	1020	13	6

Owing to the damage done by the severe winter, the grass does not appear to have averaged more per acre than the year before, but considering the time allowed for cutting (five weeks less) the average price was much more to the consumer.

The Grange Meadows.

These meadows are situate on the south side of Edinburgh, near the road leading to Liberton, and form a portion of the Grange estate, the property of Sir Alexander Lauder Dick, and are in his own occupation. A small watercourse runs down the middle of three meadows, and a carrier is cut along the sloping ground on the south side the whole length, in which it gains a considerable elevation. Very little sewage finds its way to this rivulet; it may, therefore, be considered as almost clean water. The two upper meadows and the south side of the lower one are irrigated from this watercourse, but the north side of the lower meadow gets a good supply of sewer water from the new houses built on the Grange estate: this part lies with a good aspect, and, having a pretty good supply of sewage, is much the best.

The ground has not been at all levelled; it lays with its natural fall, and has been formed at very little expense, merely cutting the carriers and rouping divisions, with a few bridges, for convenience of getting upon the lots with a cart. The lots are rather short, and consequently small: the land under irrigation is 16a. 2r. 19½p.

The roup took place on the 25th April, three days before the Craigintinny first roup. They commenced with the best part north side of watercourse; this part contained eleven lots, amounting to 3a. 2r. 11¾p.; the lowest lot made £32 5*s.* per acre, and the highest £40 5*s.* They then crossed the watercourse, and the lots 12 to 34, which run the whole length of the three meadows on the south side of the watercourse, and the two upper meadows on the north side; the lowest lot was £12 15*s.*, the highest £25 5*s.* Lots 35 to 39 lay on the top of the lower field above the lots first rouped. These lots get a supply of good sewage, but not so plentiful as the lots rouped first. The lowest price was £26 10*s.*, the highest £31 10*s.* The result of the roup may be summed up as follows:—

Lots.	Description.	Quantities.			Average price per acre.			Total amount.		
		A.	R.	P.	£	s.	d.	£	s.	d.
1 to 11	North of watercourse	3	2	11¾	35	10	0	127	1	4½
12 to 34	South of ditto	10	0	17¼	17	11	1	177	0	8¾
35 to 39	Top of lower field	2	3	30	29	5	0	85	10	11¼
39	Totals ...	16	2	19½	...		...	389	13	0½

This portion of irrigated meadow is a good specimen of how much may be done with a very small outlay—probably not exceeding £3 per acre for forming the ground.

Dalroy and Rose Bank Meadows.

These meadows lay on the west side of Edinburgh, and, although they belong to different proprietors, are all in the occupation of Mr. Thompson, and were all formed by him, and are better known as Mr. Thompson's meadows. They originally comprised about 90 acres, but are now intersected by three lines of railway, viz., the Edinburgh and Glasgow, the Caledonian, Haymarket branch, and the Caledonian and Granton branch, which crosses the two former at a higher level.

The railway companies have had to purchase about twenty-six acres of the meadow ground at from £800 to £1000 per acre; but the Caledonian company have taken about five acres of arable land from the estate in addition. The companies have paid altogether about £33,000 for land and severence and tenants' compensation.

The name Dal Roy, or King's Dale, shows that it was once waste land belonging to the Crown. The meadows form part of an extensive level, which was, in ancient times, a large loch, before the river called the Water of Leith had worked its way deep enough through its outlet on the west side of Edinburgh to drain it. This river has washed a gully by the west side of Edinburgh, nearly a mile in length, which at Dean Bridge is 100 feet deep. Rose Bank, where Mr. Thompson's house stands, was evidently an island when the surrounding lands were under water. These farms have been in the occupation of Mr. Thompson's family nearly a century.

The whole of the meadows are irrigated by gravitation, upon the pane-and-gutter system, mixed up in parts with the catch-water, and in other parts the bed system. The natural shape of the ground has been followed as much as possible. The carriers do not run straight, nor are the rouping lots square, or the panes exactly upon an incline, like the Craigintinny Meadows; but a great expense has been avoided in the formation, the best soil has been kept on the surface, and the irrigation is, perhaps, more effective.

The sewer-water which runs from the west side of Edinburgh, and supplies these meadows, is very good for irrigation; but just after it enters the meadows it receives a large contribution from Messrs. Bernard, Menzie, and Craig's Caledonian Distillery, which does not improve the quality of the water for the purpose required; indeed, some time back they occasionally let the waste from the distillery run away almost scalding hot, to the great injury of the meadows. This is now prevented, and the water is not allowed to be discharged above a certain temperature. It is kept in large tanks to cool, and during the process of cooling a great deal of sediment, from the grain used in distilling, settles to the bottom of the tanks, and is made into a paste, and sold for food for cattle at £2 per ton; but a good deal of it is dried and sold in cakes at from £6 to £7 per ton. In the process of irrigating these meadows there are four levels in succession; so planned that the water, if required, can be used four times over before it reaches the river. The upper level is taken before the burn receives the water from the distillery, and is the best part of the meadows.

From some cause, either owing to the distillery water, or the nature of the soil, which appears to be originally the washings from heath land, the grass is not so early as any of the other meadows, and the roup did not take place until the 8th May, and even then many of the lots showed too plainly the injurious effects of the severe winter.

They commenced the roup at Rose Bank, and along by the Glasgow road, where the land has a good fall; the grass was very good. Some of these lots realised £35 per acre, but great part of Rose Bank meadows was reserved, as not being in a fit state for letting. These lots were kept in hand for retailing in Edinburgh. They then proceeded with the part between the Edinburgh and Glasgow and the Caledonian Haymarket lines of railway. This part was very much injured by the frost; the lowest price made was £16 per acre, and the highest, with the exception of one lot, was £27 15*s.* This one lot was particularly fine, and was the subject of smart competition; it made £35 15*s.* They next proceeded with the part on the opposite side of the Caledonian line of railway, Haymarket branch, and then on the opposite side of the Granton branch. Here there were again some good lots watered by the sewage before it receives the distillery water. This part lays with a good fall, and drains itself well. The lowest price here was £18—the highest, £35 15*s.* per acre. This finished the rouping. The results may be enumerated as follows:—

Description.	Quantities.			Average price per acre.			Total Amount.		
	A.	R.	P.	£	s.	d.	£	s.	d.
Part by Glasgow road	4	0	0	30	0	0	120	0	0
Part between railways & south of Caledonian Branch, 39 lots	21	0	0	22	11	7½	474	4	1½
Part east of Granton Branch and lots adjoining	22	0	0	25	0	0	550	0	0
Reserved lots at Rose Bank, for retailing in Edinburgh ...	8	0	0	40	0	0	320	0	0
Reserved lots in Dalroy Meadows for retailing in Edinburgh	5	0	0	40	0	0	200	0	0
Total	60	0	0	...		...	1664	4	1½

There is one remarkable feature in Mr. Thompson's meadows—the grass is not so liable to fall as in any of the other meadows. This enables him to get an immense first crop for retailing in Edinburgh. The grass is tied in bunches about as much as a man can easily grasp with both hands, tied round with a bit of the grass. Ten of these bunches are called a "lid," which is sold for a shilling. One cart will deliver as much, upon an average, as amounts to £4 per day; two or three carts are employed.

Mr. Thompson showed the author where the grass was being cut for this purpose; it was about 2 ft. 4 in. high, and so impenetrable that the eye could not penetrate an inch into it, the blades of grass held up were about three feet high, this was on the 9th of June. The author stepped round a piece from which a ton had that morning been removed, the area was about 120 square yards, or about forty tons to the acre, this must be understood to be much above the average. When the grass first comes in it sells at £1 per ton, but as it gets more plentiful it sells at 15*s.* per ton, and has sometimes been as low as 10*s.* per ton.

Mr. Thompson states that before the meadows were made the farm would not keep above fifty head of cattle, and that it now keeps between 500 and 600 head. The commencement of the formation of the meadows dates about forty-five years back, but they have been made piecemeal, some small portions having been added within the last two or three years.

THE QUARRY HOLES MEADOWS.

These meadows are on the east side of Edinburgh, near the road leading from Abbey Hill to Leith; they form part of a farm the property of the trustees of George Herriot's Hospital, in the occupation of Mr. Skirving, whose family have occupied the farm more than a century. The meadows comprise 8a. 2r. 25p.; they were formed by Mr. Skirving some twenty or thirty years back, and are irrigated with the sewage from houses on Carlton-hill, namely, the Royal-terrace, Regent's-terrace, Carlton-place, &c. The whole is irrigated by gravitation upon the pane-and-gutter system: it lays with a natural incline with a very good fall, and drains itself well. It was originally laid out for rouping, and the rouping divisions form also the floating gutters, which run the whole length of the piece. It was formerly rouped the same as the other meadows, but latterly has been all rented by one party, Mr. McIntosh—Mr. Skirving reserving the control of the water, as in the cases of the other meadows. Previous to 1860 Mr. McIntosh paid £220 per year for the 8a. 2r. 25p., but that year it was raised to £240, and is now (1865) let for £250.

Summary of Irrigated Meadows.—Craigintinny Meadows.

	Quantities.			Price per acre.			Total Amounts.		
	A.	R.	P.	£	s.	d.	£	s.	d.
Old Meadows	190	2	26¼	29	2	10	5556	6	8¾
Engine do.	35	0	30¾	16	0	0	563	0	0
Lochend Meadows.									
North of Burn	8	0	0	40	0	0	320	0	0
Remainder of ditto ...	22	0	0	27	10	3	605	5	6
Italian rye grass	3	0	0	31	16	3	95	8	0
Grange Meadows.									
Lots 1 to 11	3	2	11¾	35	10	0	127	1	4½
Lots 12 to 34	10	0	17¼	17	11	1	177	0	8¾
Lots 35 to 39	2	3	30	29	5	0	85	10	11¼
Dalroy Meadows.									
Part of Dalroy	4	0	0	30	0	0	120	0	0
39 lots in other parts ...	21	0	0	22	11	7½	474	4	1½
Part east of Granton branch	22	0	0	25	0	0	550	0	0
Reserved lots, Dalroy ...	5	0	0	40	0	0	200	0	0
Do. in Rose Bank ...	8	0	0	40	0	0	320	0	0
Quarry Holes Meadows.									
All in one lot*	8	0	0	30	0	0	240	0	0
Bonnington-road Meadows.									
In different lots	4	0	0	24	0	0	96	0	0
Total	347	1	36¼	27	8	6½	9529	17	4¾

As Mr. McIntosh rents the meadows from year to year he does not appear to have an interest in skinning the grass off so close at the end of the season, which certainly has a great influence upon the grass in the succeeding spring, the grass is ready to cut much earlier: they began to cut a few days before the letting of the Grange meadows. From the simple manner in which the irrigation is formed, probably the expense would not exceed £4 per acre, with the exception of one piece, which requires lowering down to the main carrier.

BONNINGTON-ROAD MEADOWS.

These meadows are small in extent—only four acres; they form part of a field occupied as garden ground adjoining Rose Bank Cemetery, near to Leith, they are irrigated by gravitation, pane-and-gutter; the ground lays with its natural fall, and was irrigated at little expense, perhaps less than £5 per acre. The water is supplied from the north side of Carlton-hill, and would be sufficient for much more irrigation if there were land to be had, but the cemetery immediately joins, and after that the houses of Leith. The meadows were formed by Mr. Reed, the present occupier, who lets them out privately in lots; they average £24 per acre, and are the most recently formed of any of the meadows.

In carrying out the foregoing summary it must not be understood as representing the exact amount of money made in each individual case; it is merely the averages, carefully taken, and probably approximating very near to the fact. In order to ascertain how near the averages approximate, the exact amount of money made by the roupings of three different parts of the Craigintinny meadows was taken—namely, the Sea meadows, the Fillieside east of burn, and the Burniwards meadows—which amounted, together, to £1940 6s. 4½d.; and the average amounts of those three portions, as will be seen by the table, is £1941 19s. 6½d. According to this result it may fairly be presumed that the averages will not be far from the facts.

It appears, from the aforesaid summary, that the total quantity of land at present under irrigation with the town sewage is 347a. 1r. 36¼p.; that the total average of the money made by the roupings or sales of the grass amounts to £9529 17s. 4¾d.; and that the average per acre, upon the whole of the meadows, is £27 8s. 6½d.

Taking these sums at thirty-two years' purchase, as in the former case, the average value per acre of the land is £877 12s. 8d., and the total amount of capital represented is £304,955 16s. 8d.; and, taking the value, irrespective of irrigation, at £5 per acre per annum, gives a value of £160 per acre, and an amount of capital represented by £55,600, which, taken from the former, leaves £249,355 16s. 8d. as the amount of capital represented by the irrigations.

These figures show plainly that a quarter of a million of money, or at least money's worth, has been made of a portion only of the sewage of Edinburgh, and that every acre of land under its influence produces ten times the amount of the average of agricultural land in the country.

DWELLINGS FOR THE LABOURING CLASSES.

THE Society of Arts appointed a committee, some time since, to consider the subject of dwellings for the labouring classes, and that committee has just made the following report, which, embodying as it does the result of a lengthened investigation of the whole subject, will be read with interest:—

"The consideration of the best means of improving the dwellings of the labouring classes has for some time engaged the attention of the Society of Arts. In February 1860, Mr. Twining undertook to collect information, both financial and sanitary, with regard to the efforts then being made for providing improved dwellings in town and country. The result of his inquiry was a large and important collection of statistics, which are now deposited in his museum at Twickenham. In order to reduce the information thus collected into a shape which might be useful in future efforts in a similar nature, a special committee was appointed by the council on the 4th of November, 1863. The report of this committee, which has been printed and circulated, was prepared by Mr. Rigby, with the assistance of Mr. Twining. It contains a concise account of various blocks of dwellings and renovated houses for families and single men in the metropolis and suburban districts, under the management of societies established for improving the dwellings of the labouring classes, or of individuals interested in the same subject, together with a statement of the primary outlays, annual receipts and expenditure, and other particulars of these various buildings, arranged in a convenient tabular form.

With a view of eliciting further information on this important subject, the council invited the attendance of all those who were interested in the movement to a conference on the 26th May, 1864, and on the following day. A large number of those who had taken a leading part in providing better dwellings for the labouring classes, both in London and the country, attended the conference, and much interesting discussion took place. It was strongly urged upon the council, by this meeting, to form a committee for the purpose of taking the whole subject into consideration, and in particular for considering in what way the legislature could promote the erection of proper and sufficient dwellings for those classes who are so much in need of them.

The council accordingly, shortly before Christmas 1864, issued an invitation to various persons, whose interest and experience in the subject were likely to render their advice valuable. The committee met for the first time on the 22nd December, 1864, and continued their sittings during the spring of this year.

At the first meeting of the committee it was unanimously resolved that it was not necessary to collect facts to establish the unfitness of the greater part of the dwellings of the labouring classes as habitations for respectable and well-conducted families, or to prove that the excessive overcrowding which now exists in such dwellings promotes crime and immorality, harbours disease, and materially lessens the effective power of the working-classes, by injuring their health and shortening the duration of their lives. Nor was it considered necessary to inquire into the effect produced by these badly-constructed, ill-ventilated dwellings on the poor-rates, or into the amount of discontent which the admitted want of proper dwellings creates in the minds of the working-classes. The committee also recognised the distinction which must be drawn between associations for providing improved dwellings, by investments, for the labouring classes, the capital for which is subscribed with the double object of obtaining a fair interest on the money advanced, and of elevating the social and moral condition of the working classes; and the regular investment in such buildings by builders, who must obtain the ordinary commercial profit on capital used in business. In the first case, a dividend of 5 per cent., with an ample fund to provide for all contingencies, might be considered sufficient, whilst in the other case a very much larger return would be required. Considering these facts as fully established, the committee proceeded to inquire into—

1.—The causes which appear to retard the erection of proper house accommodation and the improvement of existing houses for the working classes in town and country.

2.—The operation of imperial and local taxation on such dwellings; and the expediency of relieving them from all or a portion of such taxation.

3.—The effect of the law of settlement and removal of the poor upon such buildings in country districts.

4.—The probable effect of extending the area of local taxation in town and country.

5.—The operation of the laws relating to the transfer of real property in small plots, and the conveyance of chambers and suites of rooms.

6.—The operation of the destruction of houses by railways and other local improvements.

7.—The desirability of facilitating the conveyance of labourers to and from their work by railway.

8.—Whether the provisions contained in the existing Acts of Parliament, for granting loans for the improvement of estates, might not be extended to the building of cottages, and if so, under what special conditions.

9.—Whether the provisionsof the Common Lodging-house Act, and other statutes relating to the public health, might not be advantageously extended.

10.—Whether there are any other means by which the legislature can promote the object in view.

Improved Dwellings for Labourers not Remunerative.—It was shown that labourers living in the metropolis and other large towns, pay a larger proportion of their income for rent than any other class in the country, and even then are unable to obtain suitable accommodation. The immediate cause of this state of things, in places where the law of parish settlement does not cause an additional difficulty, is the fact that providing such dwellings for labourers has not been found commercially remunerative. The efforts of societies and benevolent individuals are every year becoming more extensive, and from the beginning have been appreciated by the industrious classes. They have already accomplished a great amount of good, and have set an example which, it is hoped, will be more extensively followed; but it will be long before the existing evils can be more than slightly mitigated by such means. At present the dwellings provided in this manner in the metropolis only accommodate about 7000 persons, and the commercial results are not such as to encourage builders and capitalists to undertake the building or renovation of dwellings for labourers as an ordinary matter of business. It appears, from the statistics collected by the Society of Arts, that it rarely happens that such undertakings produce a higher dividend than 5 per cent. on the original outlay, and that in most cases the returns are smaller. This rate of interest may be expected to satisfy a large number of capitalists, who are willing to accept a moderate return upon capital when connected with such important philanthropic objects; but it can hardly be expected that dwellings will be provided in anything like sufficient numbers, until they can be made to produce such a return as will compensate a builder for investing his capital in this kind of property, attended as it is with so much more risk and trouble than houses of a superior class.

The difficulty of remedying this state of things is aggravated by the fact that the wretched houses, which too many of the labouring classes now inhabit, are, in their present condition, highly remunerative to the landlords. Consequently such houses fetch a high price when brought into the market. They may be made to yield a good profit in the hands of those who care nothing for the moral and physical well-being of their tenants; but the expense of putting them into proper sanitary condition, and adapting them to the wants of respectable working-men, reduces the returns so much as to render the undertaking, in a commercial sense, unprofitable.

It may be here remarked that the reproach which has been sometimes brought against societies established for providing improved dwellings, that they consider only the wants of the higher class of labourers, is not now deserved. Several societies have now under their management both blocks of buildings and renovated cottages, in which the poorest labourers are accommodated in single rooms at weekly rents of 1*s.* 3*d.* to 2*s.* 6*d.* The effect of this is to bring the societies into closer competition with the class of landlords before spoken of.

Some of the causes which tend to render such property unremunerative are beyond the control of any interference, as, for instance, the increasing value of land and buildings in the great centres of industry, and the excessive wear and tear of buildings inhabited by poor tenants. The other causes may be classed under two heads—1. Those which may be removed or modified by the legislature. 2. Those which must be remedied, if at all, by increased care and experience in the purchasing of sites, and in the erection of buildings, and in the placing them under economical and efficient management.

The committee, at the outset of their deliberations, determined to direct their attentions principally to the first of these two classes, with the hope that they might be able to suggest such amendments of the law as would secure to capitalists, investing money in this kind of property, a fair return on their capital.

Among the burdens which press upon the owners of houses or blocks of dwellings for the labouring poor, are the following:—

Rates and Taxes.—It has been commonly put forward, and is very generally supposed, that the amount of taxation, local and otherwise, to which property of this kind is subject, is so large as materially to affect the returns which a capitalist or builder would calculate upon as remunerative when contemplating the erection of dwellings for the labouring classes.

It appears to your committee, after investigating the accounts connected with a considerable number of such dwellings, that the total amount of taxation from all sources does not exceed 1½ per cent. on the whole capital invested, an amount which, even if the exemption from the whole of such taxations were practicable, is too small to exercise any appreciable influence on those contemplating the investment of capital in an undertaking of this nature. Under these circumstances, and considering the violation of sound principles involved in making any exemption in favour of any particular class of house property, the committee do not feel justified in proposing the adoption of any measure of exemption.

The house duty may be usually avoided in blocks of buildings, whose size would otherwise make them liable to it, by giving to each set of apartments a door opening to the external air, and making them thereby a distinct tenement. This is called the external gallery system.

Parish Rating in the Country.—The question of charging the relief of the poor on the parish or on the union, is one which peculiarly affects the building of cottages in the country. The present system has long been found one of the greatest obstacles to the proper accommodation of labourers on the estates on which they work; and the committee were prepared to recommend an amendment of the law by the extension of the chargeability of the poor from the parish to the union. It is a gratification to the committee that the same views on this important question have been generally recognised by the legislature, and that they are likely to be carried into operation by the bill now before parliament. The committee confidently expect that many good results will follow from the adoption of that measure.

Parish Rating in the Metropolis.—It was a subject of consideration by the committee, whether similar good results would not be produced by extending the area of chargeability in the metropolitan districts. In the discussion of this question the committee were much aided by statistical tables furnished by Mr. Farnall, and by his large experience in this subject. It appeared from these tables, in which the amount of the poor-rates were reckoned according to their proportion to the gross rental, instead of on the present capricious system of assessment, that the pressure of the rates on property in the metropolitan parishes is not so unequal as is generally supposed; and in the opinion of the committee, the inequality which really exists, does not in any perceptible degree form an obstacle to the erection of dwellings for the labouring poor. Whatever other causes, therefore, may exist to render it desirable to extend the area of chargeability in the metropolis, the committee do not think that such extension would produce any sensible effect in furthering the object specially under their consideration.

State of the Law of Real Property.—Some very interesting discussions took place on the difficulties the present state of the law of real property interposes in the way of those who are desirous of providing dwellings for the labouring poor, and of labourers who wish to become the owners of the dwellings in which they reside.

Much of the land in London and other large towns belongs to charities and other corporations and persons under disability, or is in strict settlement. Much has been done by modern legislation towards enabling trustees of settled estates and limited owners to grant building leases, and to sell portions of the estate for the benefit of the rest, under the direction of the Court of Chancery. But, independently of the expense of an application to the court, there are many cases which are not met by these enactments.

The committee suggest that corporations, limited owners, and persons under disability, should have similar powers of selling small pieces of land for improved dwellings for labourers, as they have now for selling sites for schools, under the 4 and 5 Vict., c. 38, and for literary and scientific institutions, under the 17 and 18 Vict., c. 112.

The committee had the advantage of the presence of Mr. Hare to explain his scheme for encouraging the investment by labourers of their savings in the purchase of sets of rooms in large blocks of dwellings. He proposes that each block of dwellings should be registered under the Land Registration Act, and should obtain a certificate of indefeasible title; that when that is done, the building should be withdrawn from the ordinary laws and incidents of real property, and should become personal estate; and that the apartments in it should be transferred as separate tenements, in the same manner as stock is transferred in the public funds. In this way he hopes that the tenants would become absolute owners of the rooms in which they live, paying off the purchase money in a limited period by instalments, very little more than their rent as weekly tenants. He also proposes that the management of the entire building should be vested in a committee chosen from the owners of rooms, who would regulate their mutual rights and liabilities, and enforce the good preservation and repair of the rooms and the orderly conduct of the inhabitants. The committee agreed in the expediency of any mode of facilitating and cheapening the conveyance of small tenements, but they considered that the difficulties and embarrassments, both to seller and buyer, which would arise out of any plan by which the apartments in a large block of buildings would become vested in individuals of the labouring class, would outweigh any benefit which might arise from it. The danger of such small tenements falling into the hands of speculators, who might take advantage of the necessities of the original owners; the obligation under which the working classes live of continually and suddenly changing their residence in search of work; the probability that the rooms would not be so well kept as when owned by a company, and the difficulty of arranging the mutual interests of so many small independent freeholders, seem to the committee insuperable objections to the scheme. At the same time there appears to be nothing in the present state of the law to prevent a company owning such a block of dwellings, after they have obtained an indefeasible title, from letting the sets of rooms as separate tenements on leases of any duration, subject to proper sanitary arrangements; and the committee believe that such a plan might, in many cases, be desirable. In such a case, the tenant would secure the benefit of a lower rent than if he were a weekly tenant, and would acquire the feeling of property in his own home; while, at the same time, the company would be secured by covenants and powers of entry against dilapidations and misuse of the tenement.

Loans by Government.—Numerous acts have been passed, commencing with the 57 Geo. III., c. 34, for enabling the public loan commissioners to advance money at a low rate of interest for public works and the employment of the poor, the money borrowed being repaid by instalments in a limited period. The 9 and 10 Vict., c. 79, is the act which regulates the present practice. By the 23 and 24 Vict., c. 19, the Public Works Acts (Ireland) were extended to authorise the advance of money for building cottages for labourers in that country. In England the public loan commissioners have never been authorised to advance money for that purpose; but by the 9 and 10 Vict., c. 74, they are enabled to lend money to vestries on the security of the rates for building public baths and wash-houses. By the 14 and 15 Vict., c. 34, the same commissioners are also empowered to lend to boards of health and other local authorities, in like manner, money for building lodging-houses for the poor; this act, however, is encumbered with so many conditions that it has been practically inoperative.

There is also another series of Acts (9 and 10 Vict., c. 101, &c.) enabling the inclosure commissioners to advance money in the same way to landowners for drainage and improvement of land; and under the Private Advance for Drainage Acts (27 and 28 Vict., c. 114, &c.) tenants for life, and other limited owners, can borrow money from private sources for the same purposes. The inclosure commissioners appear to have no power to advance money for building cottages, but this may be done by the Drainage and Land Improvement Companies. So far, therefore, as relates to cottages in the country, the committee do not desire any alteration in the law, but they recommend, with respect to labourers' dwellings in towns, that the public loan commissioners should have power to advance money, at a rate of interest not exceeding 3½ per cent., for building such dwellings, with due regard to sanitary arrangements. The committee believe that by such assistance the promoters might be enabled to add materially to their profits, and that the building of such dwellings would thereby be much encouraged.

Demolition by Railways, &c.—The effect of the demolition of the homes of the poor by local improvements and by metropolitan railways has been lately very much before the public. In the Earl of Shaftesbury's speech on the 31st March, in moving for an amendment of the standing order of the House of Lords upon this subject, his lordship stated that the houses for the demolition of which notice had been given under the bills before Parliament in the present session, amounted to 3500, containing a population of 20,000 persons. Although a large number of these houses will not be actually destroyed, being merely included within the limits of deviation, yet the numbers give some, though an imperfect idea of the vast amount of inconvenience and distress such works must produce among the poor. It has been proved, by careful inquiries on similar occasions in former years, that a very large proportion of those who are displaced do not leave the immediate neighbourhood, but crowd still more the already over-crowded dwellings of the same parish. And, in most cases, the committee believe that this is not merely a temporary evil, because the necessity of being near their work forms an obstacle to their dispersing into more distant places. It is the opinion of the committee that where public companies destroy houses inhabited by the working classes under compulsory powers, they ought to be compelled to provide sufficient improved dwellings within a convenient distance for the same classes in place of those destroyed, and that they should have special powers given them for that purpose. An evil is likewise sometimes perpetrated by railway companies, though probably to a comparatively small extent, by taking the yards or back premises of houses, and re-selling them for occupation by labourers, with reduced sanitary accommodation. The committee are of opinion that in such a case the company should not be allowed to sell such houses without making provision for their proper ventilation and for the sanitary accommodation of their inmates.

Workmen's Trains.—Another plan for relieving London of some part of its overcrowded population is to encourage labourers and their families to live a few miles out of London, and to transport them to and from their work in the morning and evening by cheap trains. The number of small houses now building in the suburbs of London is very great, and as working men discover by experience the advantages arising from improved health to themselves and to their families from living away from the crowded streets where they now lodge, the demand for them must increase; but even this improvement will be but temporary, and will shortly produce a new set of evils, unless the erection of these houses be carefully watched, and their drainage, ventilation, &c., be properly attended to. Precautions against overcrowding will also be as much required as in existing houses. The Metropolitan Railway Company have been trying the experiment of running workmen's trains for some months with marked success. They provide early trains from Paddington and from the City, which are used almost exclusively by working men, and they allow them to return by any train in the afternoon. No inconvenient restrictions respecting tickets are imposed, and the weekly increase of numbers is very satisfactory, and when the system is extended to Hammersmith still better returns may be anticipated. The London, Chatham, and Dover Railway Company have done the same, in pursuance of a clause in their Act, since the beginning of March. From a statement by Mr. Forbes, the general manager, in a letter quoted by Lord Shaftesbury, in his speech before referred to, it appears that the number of workmen carried by their trains has increased week by week; but the unnecessary restrictions imposed by this company upon the men using these trains must be removed before the low rates will be profitable to the company, or available, to any important extent, to workmen.

The committee desire to express their decided opinion that it would be for the benefit of the community at large that all the metropolitan railway companies should provide cheap means of transit, at convenient times, for labourers; but they hesitate to recommend that this should be made compulsory in all cases, believing that if their views of the results likely to arise from such accommodation to the working classes be correct, the directors of the railway companies will not fail to adopt them. There is also another view of the subject which must be noticed by the committee, namely the tendency of manufacturers to remove their works from the crowded centres of large towns to suburban districts. Such a practice is likely to produce very beneficial results. While healthier dwellings are provided for those who work in the manufactories, the overcrowded condition of those who are obliged to remain in the heart of the cities will be proportionally relieved.

Enforcing the Sanitary Laws. — Whatever progress may be made in building or adapting houses by individuals or societies, the great mass of the labouring population, for many years to come, must necessarily live in very crowded neighbourhoods, in houses now existing, and not originally adapted to contain several families under one roof. It is, therefore, of the first importance that the owners of existing houses inhabited by the poor, should be obliged to provide those sanitary appliances which are required for the preservation of the health of their tenants, and to check, when it occurs, the progress of infectious disease. Long experience has shown that nothing but constant inspection and compulsory measures will meet the carelessness and cupidity of the owners of this kind of property. The present sanitary laws are comprehensive, and on the whole efficient, although there are some particulars in which the committee think they require amendment, especially with relation to the inspection of houses let to lodgers, but not now subject to the provisions of the Common Lodging-house Act. The provisions of the sanitary acts are not, however, sufficiently known, nor do those who are qualified by intelligence and position to attend to the sanitary condition of their own neighbourhood, interest themselves as much as could be desired in seeing that the powers of the law are put in execution.

The committee recommend that a concise analysis of the sanitary laws should be prepared, and that the defects of the existing laws should be printed and circulated. In this way the attention of men of education and intelligence would be called to the subject, and they might be induced to take part in sanitary work in the neighbourhood in which they reside or carry on business.

In the country districts the sanitary condition of the people is regulated by the Nuisance Removal Acts, 18 and 19 Vict., c. 121, and 23 and 24 Vict., 77, and the Local Government Act, 21 and 25 Vict., c. 98; the power being vested in the Local Board of Health, or, if there be none, in the corporations of towns, boards of guardians, or parish vestries, according to the circumstances of each locality.

In the City of London the power is vested in the Commissioners of Sewers, under the acts regulating the administration of the City.

In the other Metropolitan districts the vestry or district boards are the local authorities for the removal of nuisances, under the Metropolis Management Acts, 18 and 19 Vict., c. 120, and various amendment acts.

By the 21 and 22 Vict., c. 97, the powers of the General Board of Health were transferred to the Privy Council, which has a general superintendence of sanitary matters. This branch of their duties is practically exercised by the medical officer of the privy council. The committee think that there should be a committee of the privy council constituted as a separate department, to which appeals might be made from the local authorities, and whose duty it would be to consider the recommendations dictated by the experience of the district medical officers. They also recommend that the appointment of proper inspectors of nuisances should be compulsory in all places, so that it should be the duty of such inspectors to report forthwith to the local authorities all nuisances which exist, without waiting for the complaint of other persons.

The committee further recommend that the medical officers of health should be irremovable without the consent of the privy council, and that the amount of their salaries should be subject to the approval of the same authority. The duties of these officers, if properly performed, are liable to bring them into collision with the interests of persons having influence in the vestry, and it appears of great importance that their independence of action should be secured. It appears also to the committee, that both the Nuisances Removal Acts, and the Metropolitan Management Acts, are deficient, in not giving to the local authorities sufficient powers to oblige the builders of houses to make proper provision for drainage and ventilation.

The 29th section of the Nuisance Removal Act (18 and 19 Vict., c. 121) also requires amendment. It gives power to the local authorities to take proceedings against the owner of a house inhabited by more than one family, if it shall be found to be overcrowded; but it leaves in doubt the case where particular rooms in a house are overcrowded, as well as the case of a single family in a small house of one or two rooms. It is however to be remarked that the medical officers find it impossible to interfere as they wish with the overcrowding of houses, because of the difficulty, it should rather be said the impossibility, of the poor finding accommodation elsewhere. In this, as in other details of sanitary inspection, over-strictness may become oppression, and aggravate, instead of alleviating, the hardships of the poor. Until more and better dwellings are provided, and until the labouring classes have learnt more fully themselves to appreciate the blessings of air and cleanliness, no sanitary regulations can be satisfactorily carried out.

The committee in conclusion recommend to the council:—

1. That corporations, limited owners, &c., should have increased power to sell land for the erection of dwellings for labourers, under conditions as to proper drainage, ventilation, and sanitary regulations.

2. That the public loan commissioners should be authorised to lend money, at a rate not exceeding 3½ per cent. per annum, for building dwellings for the labouring classes, under suitable guarantees and with due regard to sanitary arrangements.

3. That in all future railway acts, and acts for local improvements, when houses inhabited by the working classes are destroyed under compulsory powers, such companies should be compelled to provide, within a convenient distance, other dwellings in lieu of those destroyed.

4. That the following amendments should be made in our sanitary laws:—

a. That the appointment of inspectors of nuisances throughout the country should be compulsory.

b. That increased power be given to the proper local authorities, to oblige builders of houses to provide adequate drainage and ventilation.

c. That the medical officers of health should be irremovable without the consent of the privy council, and that the amount of their salaries should be subject to the approval of the same authority.

d. That houses in which lodgers are taken, especially where particular rooms in a house are overcrowded, should be brought under more efficient inspection.

5. That with the view of extending an accurate knowledge of the powers contained in the various acts relating to the removal of nuisance, the council is recommended to prepare and publish

a concise analysis of the existing law, calling the attention of the educated classes to this important subject, and pointing out how they may, merely by a little attention and exertion, confer most important benefits upon a large mass of working people and upon the country generally.

6. That the council be requested to take such measures as it may think advisable to bring the first four of these recommendations as soon as possible under the notice of Her Majesty's Government."

CREEDS AND TEMPLES: THEIR RELATION TO ONE ANOTHER IN PAST AND PRESENT TIMES.*

By H. H. Statham, Jun.

On a first view of the subject, it would appear that under no circumstances might we be so well justified in looking for an entirely new style of temple architecture as under the rise and spread of a religion so new in character, so completely in contrast to all the existing faiths of the then civilised world, as the Christian. But the absence of such a style is the most striking exemplification of the fact, which meets us elsewhere in history, that the rise of a purer religion or the reformation of an old and corrupted one, is always accompanied by a corresponding neglect of temple architecture. This was commented upon as early as the fifth century by Isidore, who remarks "that in the time of the apostles, when spiritual gifts abounded, there were no temples; but now the buildings are adorned more than necessary, while the church has fallen into disgrace." During the first years of Christianity, of course, the persecution to which it was subjected would have prevented the erection of any public places of worship; but, though during great part of the third century the Christians enjoyed great toleration, and their numbers rapidly increased; and though even in the second century we find evidence of an organised church government, represented by bishops and presbyters, there is nothing to show that there were, at this time, any buildings specially erected and set apart for purposes of worship. And when, at the commencement of the fourth century, the empire under Constantine became nominally a Christian one, and the church emerged from its obscurity into comparative power and honour, the necessity for some public place of meeting was supplied neither by a new style of temple nor by the adaptation of former ones; but by the most convenient buildings that came to hand, the disused basilicæ or halls of justice of the extinct heathen empire.

There was more than one reason for this choice. The early Christians regarded with horror everything connected with the old religion; the gods were to them dæmons, the temples polluted by pagan associations. The basilicæ, besides that they were free from this objection, were in fact so admirably adapted for the purposes of the Christians, that the new churches, when built, were for a long time exactly on the same model. They presented in the great hall an admirable area for a large assembly, while the seat in the centre of the apse, from which the prætor had administered justice, formed a dignified throne for the bishop, and the presbyters occupied the semicircular seats formerly appropriated to judges and lawyers. This simplicity of arrangement, however, did not long continue, for church government was already in a much more advanced state than church building; and so early as the beginning of the fourth century the idea had developed itself of a peculiar sanctity residing in the clergy, and of the necessity of their separation from the laity, who were already beginning to be ruled with a rod of iron. And though down to the ninth or tenth century the basilica remained the principal type of church, the actual halls themselves were not very long retained as places of worship, owing to a feeling which led the people to seek out sites consecrated by the martyrdom of saints. There is a somewhat detailed account given by Eusebius (about A.D. 330) of the arrangement of a new church built in his time at Tyre, which, taken in connection with the plan of the old Basilican church of St. Peter's at Rome, gives a good idea of the general arrangements of the churches of this period, and the motives which governed them. Eusebius describes how the bishop "raised a stately portico against the rays of the rising sun" (for the orientation of churches was not at all universal at this time, and in Italy never became a rule). "After you have come within the gates he has not permitted you to enter into the holy place with unwashed feet, but having left a large vacancy between the portico and the temple, he beautified this vacant space, having enclosed it as a quadrangle, with four opposite cloisters, supported on every side with pillars. Here also he placed the mysterious symbols of the sacred purgations; to wit, fountains built opposite to the front of the church, which afforded water for those who entered the sacred precincts to wash in. And this place yielded a very commodious mansion for those who wanted instruction in the first principles of religion." After speaking of the decorations, he proceeds—"Having thus finished the temple, and adorned it with the highest thrones in honour of the prelates of the churches, and with benches placed in order all over the church, he placed the holy of holies, the altar, in the midst; and that the multitude might not come within these holy places, he enclosed it with wooden rails resembling net-work, which were curiously and artificially framed and carved." This last passage has given rise to some pretty sharp paper warfare, as to whether the altar was placed in the chancel or not. I believe the explanation is, that Eusebius, when he says "all over the church," means, by a carelessness of expression, "all over the chancel," — the part railed off, and appropriated to the clergy; for we know from contemporary church historians that the congregation was not allowed to sit at all, but that benches were always placed within the cancelli, for the inferior clergy; and in this case, the expression, "in the midst" applied to the altar, would indicate that it was within what we should now call the "chancel." The different parts of the church were carefully partitioned out for different classes of worshippers. The atrium was, as Eusebius indicates, appropriated to the untaught converts, while the side of it next the church, called the narthex, was the place for penitents who were under temporary excommunication; an arrangement occasionally revived in mediæval times in what are termed the Galilee porches of our cathedrals. The lower end of the church, next the entrance, was partitioned off by a barrier about one-third the distance up the nave, and was appropriated to the catechumens who were still under instruction, and were only allowed to hear the reading and preaching, not to join in the prayers or sacraments: hence this was called the locus audientûm. Beyond this barrier was the locus fidelium, the place of the faithful, who alone were permitted to join in the more solemn parts of the service. The men were always stationed on the right side (what would with us be the south) of the church, and the women opposite, a barrier dividing the two; an arrangement which the wisdom of certain modern ecclesiologists has revived. The altar was shrouded from the people by a curtain, which was withdrawn during the celebration of the eucharist. On each side of the chancel was a small chamber; that on the south side called the diaconum, being for the reception of the vestments and other furniture of the church, which was under the ca e of the deacons; that on the north the prothesis, for the keeping of the sacred vessels and elements, which were set out in order there previously to the celebration of the communion. These two small chambers, generally built out on each side of the church, form, I suspect, the real origin of the transepts and of the cross form, which had a symbolism tacked on to it afterwards with which it had originally nothing whatever to do. The small size of the apse indicates that the clerical body were not at this period very numerous, but we cannot go much further without finding decided evidence of their increase. Custom and precedent led to the retention of the simple apsidal termination for some time after; but as the clerical ranks were swelled, and a new order of choristers founded among them by Pope Gregory in the sixth century, we find that in order to give room for them the chancel was continued out into the church, and divided off from the people by a screen all round it; and into it the reading desk or ambo was conveyed from its original position on the bema. The true chancel, as we understand the term, did not in reality develop itself till about the eleventh century, and owed its importance to a liturgical cause. It was the outward expression of the dogma of transubstantiation, which began to make itself felt at the beginning of that century, and gradually became a received faith, till it was formally confirmed by a general council in the year 1215. The belief in this miraculous change of the elements invested the priesthood who performed it with an additional sanctity, both in their own estimation, and still more in that of the people; and, accompanied as it was by the elevation and adoration of the host, it naturally demanded that the priests, in the performance of this rite, should be separated more decidedly than

* Continued from page 152.

ever from the people, and that the simple apse should be expanded and beautified to form a fitting arena for the celebration of so great a mystery. The rise of the chancel in the eleventh and its progressive importance up to the thirteenth century, as exhibited in the French churches, keeps pace almost exactly with the development of this doctrine, forming one more evidence of the coincident growth of religious architecture and religious superstition. In France, however, the chancel took a peculiar form, modified by the influence of circular churches, about which something must be said.

The early basilican churches of the fourth century were never complete without the addition of a circular building, generally called a baptistery, and probably used for the performance of all ceremonial rites, as funeral services, &c., the basilica being the place of general assembly for the ordinary public worship. This form was, as we have noticed, borrowed from the circular Roman temples dedicated to Etruscan deities; and the change may be traced from the little temple of Vesta at Tivoli, which has an external colonnade, through the tomb of Sta. Costanza, where there is both an external and internal colonnade, to the baptisteries at Nocera and elsewhere, where the external colonnade has disappeared, and the style has become an internal one. The position of this baptistery was at first rather uncertain, but after the fifth century it was pretty generally placed at the west end of the basilica, as symbolical of the entry into the church by baptism. But as a principal object of these buildings was the admission of new converts into the church with all possible solemnity, it followed that from the seventh century, when infant baptism was introduced, and the reception of barbarian converts into the church became less frequent, the baptisteries fell rather into disuse, and were replaced by the font near the west door of the basilica. The circular form, however, long continued to be connected with the idea of a ceremonial church. Such was the one, before mentioned, built by Charlemagne to be the scene of the coronation of living emperors as well as the sepulchre of departed ones. This also, I think, was one motive for the universal preference of the circular form by the Templars, with whom the ceremony of investiture was so important. In the early Gothic period, the circular form on a large scale appears in conjunction with the rectangular form, both in France and Germany, but with the remarkable distinction that in the former country the circular part is always the choir or chancel, in the latter it is always the nave. The reason for this difference seems to be that the French always retained the idea of the connexion of the circular form with the more sacred and ceremonial parts of the ritual, and therefore, when they used that form, always appropriated it to the clergy; while the Germans, admiring the form architecturally, and being less under ritualistic influence, used it for their congregational churches, the straight-lined chancel being added, as the clergy increased in numbers and influence, as a place for their worship apart from the people. In the complete Gothic period, when the Roman see had acquired such general authority, the Germans forsook the circular for the orthodox basilica form; while the circular chancel in France merged into the polygonal apse characteristic of French cathedrals.*

The peculiarities of the Byzantine plan of church were due to architectural and not to ritualistic influence, the ritual being in early times very similar to that of the Western Church. Some of the points of difference which existed or arose between the two churches may, however, be noticed as influencing the buildings erected for Eastern worship. One of these was the placing of the women in galleries, instead of dividing them from the men by a barrier on the ground-floor. The galleries and the two-storied porch for this purpose form a marked feature in the design of St. Sophia at Constantinople. A more important point was the dislike in the East to sculptured decoration, which rose in the eighth century to violent iconoclasm, and gave additional impulse to a highly developed style of pictorial decoration, first in the form of mosaic, and later in that of painted pictures, for the exhibition of which a screen was always erected, called the *iconostasis*, completely across the front of the chancel, leaving only a doorway for the priests to enter, an arrangement which, whatever the interest of the pictures, must be very destructive of architectural effect. The Russians, when converted to the Greek faith, carried this pictorial decoration to the extreme, their churches becoming, from floor to roof, complete picture exhibitions, even the columns being painted round, after the manner of the Egyptians, with representations of the lives and miracles of the saints; and the porches adorned with figures of the great heathen poets and philosophers, each illustrated by some sentence from their writings which might represent them as the pioneers of Christianity. This is, I think, a very legitimate kind of symbolism; and if fresco-painting were introduced into our churches, the idea would be worth remembering.

It does not appear that the Greek church ever adopted the dogma of transubstantiation with the same significance which was attached to it by the Roman; hence the chancel is but little developed. The persistency with which the style has been practised, and the same plan retained nearly to the present day, is a striking exemplification of the intense conservatism of the Greek Church, which regarded the innovations of the Roman pontiffs very much as the latter, in their turn, regarded those of Luther and Wickliffe.

The rise of Mahometanism, the greatest religious crisis between the Christian era and the Reformation, can hardly be said to have given rise to any form of temple peculiar to itself. The first founders of the religion were a Semitic people, and the religion itself the outbreak of the Theistic feeling so peculiar to that people, which had laid dormant since the extinction of the Jewish religion, and which was very unfavourable to anything like a pompous or ceremonial worship. With regard to the externals of worship, indeed, the Moslem was to the Eastern Church very much what the Puritan was to the Western,—both equally indifferent to liturgical forms, both regarding the spirit of the worship rather than the place in which it was performed. To the true Mussulman there was, in fact, but one sacred temple, that of Mecca, which was a comparatively insignificant building; and though, when the religion spread and gained power in other countries, it was found advisable to raise buildings commensurate in size and beauty with its importance, the plan of the original temples of the proselytized people was almost always adopted, and even the style of architecture, though this became speedily modified by the rich and brilliant fancy of the Saracens. Still, I do not think that the peculiar class of ornament and style of architecture called Saracenic can be rightly considered as the outgrowth of the spirit of the religion, but rather as arising from that taste for rich but sensuous beauty peculiar to the Arabic mind, and of which the Mahometan Paradise, with all its voluptuous delights, was only another development, — a concession, in fact, to the popular feeling; though, when the religion was adopted by a new people, these ideas may have re-acted upon the style of the architecture. To call the Saracenic the parent of the Pointed Gothic, through the medium of the Crusades, is surely quite overstating the case. It may have given additional richness and variety to the latter; but, even if it contributed the Pointed arch, this was only anticipating what the necessities of Gothic vaulting must have evolved very shortly after.

In tracing the variations in plan among the Latin churches, no reference has been made to the phases of architectural style through which those churches passed; these being, in fact, almost wholly independent of religious influences, and none of them becoming elaborated into a distinct and complete style till we arrive at the true Gothic period in the thirteenth century. Here we meet with the third great temple style of the world, as complete in its way as the Egyptian and Greek, and, like those styles, arising under the influence of Polytheism; for every impartial student of ecclesiastical history must perceive that the faith of the thirteenth century, with its hosts of martyrs and saints, the objects of direct adoration, was in fact as completely polytheistic as that of the Egyptians. The complete Gothic may be most fitly characterised as pre-eminently the monastic style. Monasticism had, indeed, existed for a long time before; but in the eleventh century it acquired great additional wealth and influence under the fostering care of the Roman pontiffs, who took it under their special protection. The powerful and richly endowed conventual establishments which arose at this time soon gave expression to their religious feelings in those great piles of building, of which the monks were themselves often the architects; and which, in the spirit of aspiration which everywhere pervades them, in the entire subordination of the horizontal to the vertical principle, are the most complete outward exponents of that morbid excess of religious zeal, that entire forgetfulness of the practical, which, be it remembered,

* For the above explanation I am mainly indebted to Mr. Huggins, the author of "the Course and Current of Architecture."

existed at that time nowhere out of the cloister; as the comparison of the monastic with the secular poetry of the period, of Bernard of Clugny* with Chaucer, will abundantly prove. There is much, too, in the style to remind us of the Egyptian; the same vistas of aisles and columns, the same profuse use of symbolism, the same love of coloured decoration, not of the most refined or artistic kind, is common to both styles; nor are the surrounding circumstances dissimilar. Both nations† were, at the culmination of their respective styles, in much the same state of civilisation; in both the dominant sect was a numerous and powerful priesthood, held in superstitious reverence by an ignorant laity, whose chief religious instruction was derived from the paintings on the walls and windows of the temples. There is, however, one important distinction; the Mediæval superstition had at least a background of truth: the saints who were worshipped were invested with characters above, and not below, ordinary humanity: instead of the fantastic deities of the Nile,

"Isis, Osiris, and the dog Anubis,"

or the ferocious Siva and obscene Vishnu of the Hindus, we have St. Peter and St. Catherine: it was a worship tending to expand the feelings rather than to contract them: and we find the buildings expressing this distinction; for while the Egyptian and Indian perpetually narrow as they are penetrated, till the shrine is found to be the meanest part of them, the Gothic temple, on the contrary, represented in such a plan as that of Rheims, with a comparatively small entrance, widens and expands as the shrine is approached, leading the eye continually upward and onward, and justifying Coleridge's remark, that the spirit of Gothic architecture was "infinity made imaginable."

(To be continued.)

CONSTRUCTION OF DOCK AND QUAY WALLS WITHOUT COFFERDAMS.‡

By Daniel Miller.

(With an Engraving.)

The first operation in the construction, when the water is not sufficiently deep, is to dredge out two parallel trenches to 17 feet below low-water, for the foundations of the walls. A staging of timber piles is afterwards erected in the line of the pier over the whole breadth, for carrying the tramways, travelling cranes, and piling engines. Cast-iron guide piles are then driven from the staging with great precision, 7 feet apart in the line of the face of each quay wall. These piles are driven till their heads are near the low-water line, and they form guides for putting down the stone facing. They are connected at the top transversely by wrought-iron tie-rods stretching through the pier, cottered into sockets and binding the heads together. At first it was thought that there would be some difficulty in driving the iron guide-piles with the required exactitude, but this was overcome by pile engines of peculiar construction, devised by Mr. William York, one of the contractors. These engines are shown at Figs. 10, 11, Plate 15. They travel on the rails of the scaffolding, and are furnished with long arms projecting downwards, strongly stayed by diagonals, and forming a trough into which the pile is placed, and from which it is driven by the pile engine in the manner of an arrow from a cross-bow, being obliged to go down perfectly straight.

The ground is very unequal, the hard substratum, or red 'till,' being in some places 20 feet below the bottom of the wall, the upper strata being mud and soft sand. In such cases timber piling, driven to the same level as the iron piles, is used to form a platform for sustaining the part of the wall above low-water; but where the ground is firm this is not required. When the proper depth has been dredged out and the piling driven, a bed of hydraulic concrete 3 feet thick and 20 feet wide is deposited in the trenches, to form a base for the wall to spring from, and to give a large bearing surface. Into the grooves formed by the flanges of the iron piles, large granite slabs from 18 inches to 2 feet thick are slipped, the bottom one resting on the concrete base and on a projecting web cast on the piles: not more than three stones fill each compartment between the piles 16 feet in height and 7 feet in width. These stones slip into their places with the greatest ease, and form the face of the wall under water. Behind this facing hydraulic concrete is lowered under the water in large boxes having moveable bottoms, and is discharged in mass to form the body of the wall. To confine this at the back before it has set, loose rubble stones are deposited and carried up simultaneously with it. The hearting of the pier, consisting of hard 'til,' stones, and gravel, is deposited afterwards, and the whole carried up to the level of low-water.

The entire mass, piles and stone facing, concrete backing and hearting, is allowed to consolidate for a sufficient time; after which the heads of the iron piles and the granite facing blocks are capped at the level of low-water by a granite blocking or string-course, and the upper portion of the walls is carried up in freestone ashlar and rubble. The remainder of the hearting between the walls is then filled in, and the whole is finished with a granite coping and causeway. The walls are 33 feet in height from the foundations, 11½ feet thick at the concrete base, and they diminish to 5 feet thick at the top.

Particular care is taken with regard to the hydraulic lime. It is burnt at the quarries, but is brought from thence in the 'shell' by the railway in covered wagons so as to preserve it from wet. It is ground at the harbour works, for which purpose, and for mixing the mortar, there have been erected four vertical double-roller mills and two sieves, drivenby an engine of 20 H.P.

In the part of the pier which has been already executed, the stone facing under low-water being made to slip into the groove formed by the flanges of the iron piles, the outer flange is left exposed to the action of the salt water, which no doubt will in the course of time exert an injurious effect upon the iron. (Plate 11, Figs. 3 and 6.) To remedy this it is intended in the remainder of the work to reverse this plan, and to make the grooves in the stone facing into which the outer iron piling will fit. (Plate 11, Figs. 1 to 4.) The stone blocks will therefore overlap the iron piles, and form a continuous stone facing, so that no part of the iron will be exposed to the action of the salt water. The grooves will be filled from the top with cement, which will enclose the iron flange and effectually preserve it.

When the whole extent of the seaward pier is completed, the interior operations for the harbour will be proceeded with. This pier will serve as the principal cofferdam, and the entrance will be closed by a short cofferdam about 100 feet in length, and then the water will be pumped out from the enclosed space; after which the excavation and the construction of the interior walls surrounding the harbour will be commenced. It is not intended to describe these operations, as they do not possess much novelty.

The cost of the outer or sea piers, 1200 feet in length and 60 feet wide, constructed in the manner described, will be £63,000.*

The concrete employed is formed of Arden hydraulic lime, iron-mine dust, sand, gravel, and stone chips, the lime and the mine dust being well ground under edge stone mills before being mixed with the other materials. The proportions are by measure: one part of ground lime, half a part of mine dust, one part of sand, and three parts of gravel and stone chips. Immediately after being mixed, and when brought to a proper consistency with water, it is conveyed to where it is to be used, is let down under water in the discharging boxes, and in a short time sets very hard. The boxes used are either of iron or of wood, and contain one cubic yard each. Those of iron are found to be preferable, as the buoyancy of the wooden

* The great work of this really fine poet "De contemptu mundi," some parts of which have been lately translated, might be almost described as "a French cathedral versified." The extravagant spirit of aspiration, the redundancy of ornament, the want of artistic self-restraint, are the same in the book as in the building. Chaucer has none of this; and it is remarkable that whenever he alludes to "the church," it is entirely as a spectator *ab extra*.

† The Celts, the chief originators of the Gothic style, are probably connected more or less with the Turanian race. Fergusson, indeed, speaks of them as "undeveloped Aryans;" but may it not be more correct to call them "highly developed Turanians?" Philology, I believe, bears out this view to some extent.

‡ Concluded from page 132

* It has recently been decided to increase the area of the Albert Harbour, by building the south quay 90 feet further back than is shown on the plan (Plate 9, Fig. 1), the necessary land having been acquired. In connection with the harbour works, and to dispose of the materials from the excavations, amounting to nearly half a million cubic yards, it is intended to form an esplanade or embankment 100 feet wide, along the shore of Fort Matilda. This will be faced on the seaward side by a substantial wall 6000 feet in length, with landing-stairs opposite the principal streets, and the wall will be surmounted by an iron balustrade. The cost of the several works will be—

Albert Harbour and Albert Quay	£160,000
Sea-wall and roadway of esplanade	20,000
Land	50,000
Cranes, rails, &c.	10.000
Total . .	£240,000

ones renders them somewhat unmanageable in a tideway, after their contents have been discharged.

The works of the Albert Harbour are being executed under the immediate superintendence of Mr. John Thompson, C.E., as resident engineer, the contractors being Messrs. W. and J. York. This mode of constructing walls in deep water without cofferdams has proved very successful, and a sea-pier of great solidity and durability has been formed at a comparatively moderate cost.

In constructing quay-walls on the foregoing principles, different modes of forming the stone casing may be employed; and particularly where stone of a softer nature than granite, such as limestone, or freestone, is used, a still more efficient outer casing may be obtained. (Plate 11, Fig. 5.) In it, blocks of stone, having orifices or holes cut in them, are strung or put down over the iron piles, so as completely to enclose them. These blocks have also grooves or projections on their sides, in which are slid down intermediate slabs or blocks of stone, having corresponding grooves or projections. A continuous facing of stone, having all the stones locked into each other, is thus formed, and the iron piling effectually enclosed. It was on this principle that the facing under low-water was intended to have been formed at Greenock, previous to its having been suggested to employ granite instead of freestone. Still further to protect the iron from the action of the salt water, the holes round the piles would be filled up from above with cement well rammed down, so as to fill up all the joints, and to unite the stone and iron together. This plan admits of the iron piles being kept further apart than when single blocks connect the piles. Concrete backing may then be filled in, and the structure be completed as previously described. Temporary sheet piling or boarding, instead of loose stone, may be employed to keep the concrete in its place until it has set. In many cases blocks of béton, which can be easily moulded into the shapes required, may be advantageously substituted for stone in the facing, as it has been proved by experience that, when properly made, they possess the requisite strength and durability.

The range of different purposes to which this system of founding marine structures is applicable is very extensive, and works such as the formation, re-facing, or re-construction of quay-walls; the foundations of lighthouses, beacons, or forts which may require to be made in the sea; the construction of breakwaters inclosing harbours of refuge; may be effected with a speed, facility, and economy not hitherto attainable. The applicability of this system to the construction of breakwaters, and the necessity for some mode by which the cost of these works may be lessened, seem to the author so important as to deserve further remarks.

Application to the Construction of Breakwaters and Harbours of Refuge.

Although various royal commissions and parliamentary committees have elicited much valuable information on this subject, the main object of diminishing the enormous cost of these works and providing a durable and substantial, and at the same time economical, barrier to the force of the sea, is as yet a desideratum. So important indeed has it become, that in 1860 a select committee of the House of Lords was appointed to inquire how far it might be practicable to adopt some plan for the construction of breakwaters and harbours of refuge less costly than the system of solid masonry then in use. Various plans were discussed, and amongst them floating breakwaters; but the investigation failed to establish any effectual substitute for the present modes of construction.

The plans about to be described will, in the author's opinion, have a material effect in filling up this want. Before proceeding, however, it will be necessary to refer briefly to the principal modes of construction hitherto adopted, and to consider the peculiar phenomena by which such structures are affected.

The most common mode of forming breakwaters is the 'pierre perdue,' or 'long slope' system. This is simply the deposit in the sea of a vast amount of loose rubble stone, rising to about the level of high-water, allowing it to take its own level and to be acted upon by the sea, until its section assumes the permanent form which this action gives it. The seaward side obeys the laws of ordinary sea-beaches, and forms itself into a long sloping shore, involving the employment of an enormous amount of material before the mound reaches the height to give the required protection. Such a system is only applicable where stone is abundant, and can consequently be deposited at a cheap rate. Of this system the breakwaters at Plymouth, Cherbourg, and Holyhead are examples.

In situations where stone is not abundant, the opposite principle, called the 'vertical system,' is adopted. In this mode the walls are built upright from the bottom, and as all the material below low-water is put in place by diving apparatus, and is of an expensive nature, the cost of a work executed in this way is very great. The Dover breakwater, in course of construction, is the most prominent example. It is built up solid from the bottom of the sea, the exterior facing being of ashlar granite blocks rebated or checked into each other, and the hearting of rectangular blocks of concrete, built in the same way as ashlar masonry up to the level of high-water, above which it is filled in with liquid concrete. (See Fig. 14, Plate 15, which is a section of the breakwater.)

Besides these systems, which may be taken as the extremes, an intermediate form of section, combining both to a certain extent, is adopted. It consists in carrying up a rubble mound to within a certain depth below low-water, and upon this, building the remainder of a vertical construction. The Alderney breakwater may be taken as representing this system to a partial extent.

It has been a subject of discussion as to whether the 'long slope,' or the 'vertical wall' was the better section for breakwaters, and as to the relative force of the sea exerted upon them. The observations which have been made on waves may be said to have settled this point in favour of vertical walls, as it has been clearly shown that waves in deep water are chiefly oscillatory in their character, the fluid having little progressive motion in itself, and consequently exerting but little force on objects opposed to it; but in shallow water waves assume an entirely different character as they acquire progressive motion, becoming waves of translation, in which the fluid is carried bodily forward in a horizontal direction, and in consequence it strikes any body opposed to it with great percussive force. Vertical walls, therefore, which rise from the deep water, being only subject to the oscillatory movement of the waves, are least exposed to the destructive effects of storms. The evidence taken before the royal commission in 1859 seemed to be conclusive on this point, and the opinions of the commissioners, as developed in their report, may be considered to have set this subject at rest. But whatever difference of opinion there may still be upon this matter, there can be no question as to the vast saving of material by vertical walls, and of the great economy which would result, provided a simple and easy mode of construction could be adopted. The vertical system has, besides, the great advantage of being applicable in many cases as quays for vessels lying alongside to load and discharge, which may be turned to valuable account both for commercial purposes, and in times of war, for the rapid shipment or debarkation of troops, stores, and other material.

The experience, however, derived from the formation of the great breakwaters on the 'pierre perdue,' or 'long slope' principle, such as Plymouth, has been very valuable. The examination of the sections which the materials assume, shows that the great disturbing actions of the sea, or conversion of the waves of oscillation into those of translation, does not extend to any considerable depth; as it is found that the long sloping beach terminates generally at from 12 feet to 15 feet below low-water, after which the inclination becomes much steeper, the materials assuming nearly the form due merely to the natural angle of repose, as if unacted upon by any force except that of gravity. The inclination on the seaward side within the tidal range, and to the depth of 12 feet or 15 feet below low-water, is generally five or six horizontal to one vertical, but below that depth it is only from one to one and a quarter horizontal to one vertical. It is the long slope which these breakwaters assume to a certain depth, that causes the enormous absorption of material; but it appears that a mound of rubble may be deposited to within a certain distance of low-water which will not have this long slope, and consequently will only require a comparatively small quantity of material. The consideration of these facts shows, that in the generality of cases the vertical and 'pierre perdue' systems may be combined with advantage and economy, by first depositing a rubble mound to about 15 feet below low-water, and from that point carrying up the remainder of the breakwater by vertical walls.

A great improvement in the facility of constructing these breakwaters, when such an immense quantity of material has to be deposited, was the introduction, by the late Mr. Rendel, of timber staging carried on piles in advance of the work, and sustaining lines of rails by which the material can be brought down and be deposited in the sea with a rapidity before unattainable. The consumption of timber is, no doubt, very great, as much has to be left imbedded in the work, and there is considerable destruction besides; but this is amply compensated by other advantages. By this system an average of about a million tons of stone a year have been deposited at Holyhead, and a similar plan is pursued at Portland.

Massive staging is also employed at the vertical breakwater at Dover, for facilitating the building operations. Indeed, staging may now be considered essential in the generality of cases for the economical construction of such works.

The breakwaters of the French engineers are generally formed 'à pierre perdue,' but upon a different method from that pursued in this country. Thus, at the Plymouth breakwater, only large blocks of rubble stone were deposited, the small being thrown aside, and at Holyhead and Portland the large and the small rubble were deposited promiscuously; while the French engineers usually employ the small rubble for the core and reserve the larger blocks for the outer coating. Furthermore they protect the seaward side by blocks of beton, thrown in to take their own position, and of such a size, (generally from 20 tons to 30 tons,) as effectually to resist displacement by the utmost force of the waves. These blocks assume a slope as steep as one to one under the water line, so that the mass of material in a breakwater thus constructed, is considerably less than where smaller materials are employed for the seaward face. The moles of La Joliette and Napoleon, which enclose the harbour of Marseilles, are excellent examples of this mode of construction.

Having thus glanced at the general principles which affect breakwaters, and described the modes of construction usually adopted, the conclusion to be arrived at appears to be, that the vertical system is that which best resists, or rather averts, the destructive action of the sea, and requires the smallest amount of material. However, both systems, the 'long slope,' and the 'vertical,' as at present carried out, are very expensive; the former from the quantity of material which is required, the latter from the costliness of the material and the mode of construction. The one system may be characterised as involving the maximum in quantity and the minimum in cost of material; the other, on the contrary, the minimum in quantity and the maximum in cost of material. The object sought to be attained by the system about to be described is to effect a minimum, as far as possible, both in the quantity and in the cost of the material.

According to circumstance, breakwaters on this system would be constructed either wholly vertical, extending from the bottom, or partially vertical, springing from a rubble mound. For the sake of comparison, the mode proposed by the author (Plate 11, Fig. 7, 8, and 9,) is designed to suit the conditions usually prevailing; say a range of tide of 15 feet, and a depth at low-water of 6 fathoms, being about the same as at the Plymouth breakwater, and as at Hartlepool, Filey Bay, and the entrance of the Tyne, where the most important harbours of refuge have been recommended by the royal commissioners. The section (Plate 15, Fig. 13) represents a breakwater with a parapet, but this is not indispensable to the main object of a breakwater, and is only required in certain cases, as where the inner side is to be used for commercial purposes. Where the parapet can be dispensed with the top of the breakwater may be capped with large bricks of beton or stone, of such a weight as not to be displaced by the heaviest seas. Fig. 12, Plate 15, is a section of one so constructed.

The principal feature of the new plan is a framework of iron formed of piles or standards and ties, which serves as the staging for all the constructive operations, and afterwards becomes an essential portion of the structure, by binding together a strong casing of stone or other sufficiently durable material, which encloses and forms the facing of the breakwater, allowing the interior to be filled up with loose rubble or other cheap materials, which may be cemented into a solid mass by means of liquid beton or concrete. It will be preferable for breakwaters to make the standards of wrought-iron, and in the generality of cases it [illegible] not be necessary to drive them into the ground, but simply [illegible] them in place.

The mode of proceeding is to erect the iron staging in advance of the work, which may be done either by driving, screwing, or guiding the piles or standards from a machine placed on the platform, and travelling along as it progresses. This machine will have long guides firmly stayed and set accurately in position, into which the iron piles will be placed, and then driven in a similar manner to that pursued at Greenock. When two piles are erected in place they are connected transverely by iron ties, and by the temporary platform at the top for bearing the rails, and the piling machine is then moved on to drive the next set, and so on. Following this operation come the wagons depositing the material to form the rubble mound, which collecting round the lower parts of the standard, firmly fix them in their places, and give stability to the staging. When the mound has risen to the required height, say 18 feet below low-water, the cranes from the staging above commence lowering the casing blocks for the facework. These are made to enclose the iron standards, and are formed so as to be arched or locked into each other, and thus to resist any pressure arising from the backing. They can be made to break bond, or to slide down without breaking bond, as may be considered desirable; but the former plan permits the standards to be kept at a greater distance apart, and the blocks to be of less dimensions and at the same time of greater strength.

Simultaneously with the building of the casing, the hearting of the work, rough rubble, or other suitable material, is to be deposited from the wagons on the staging, filling in from the centre, while backing of beton or hydraulic concrete will be lowered down in large boxes and discharged behind the stone casing, consolidating and cementing together the rubble hearting as it is filled in and falls down.

It will be observed that the whole of the facing is rendered continuous, and by all the blocks being arched or grooved into each other, it is impossible that any individual block can get out of place. This is a danger greatly to be feared in structures of this kind built in the ordinary way, as the action of the compression of the air in the joints of the masonry by the pressure of the waves, and the after-expansion when the waves retire, is sometimes so great as to blow out the stones, thereby endangering the whole structure.

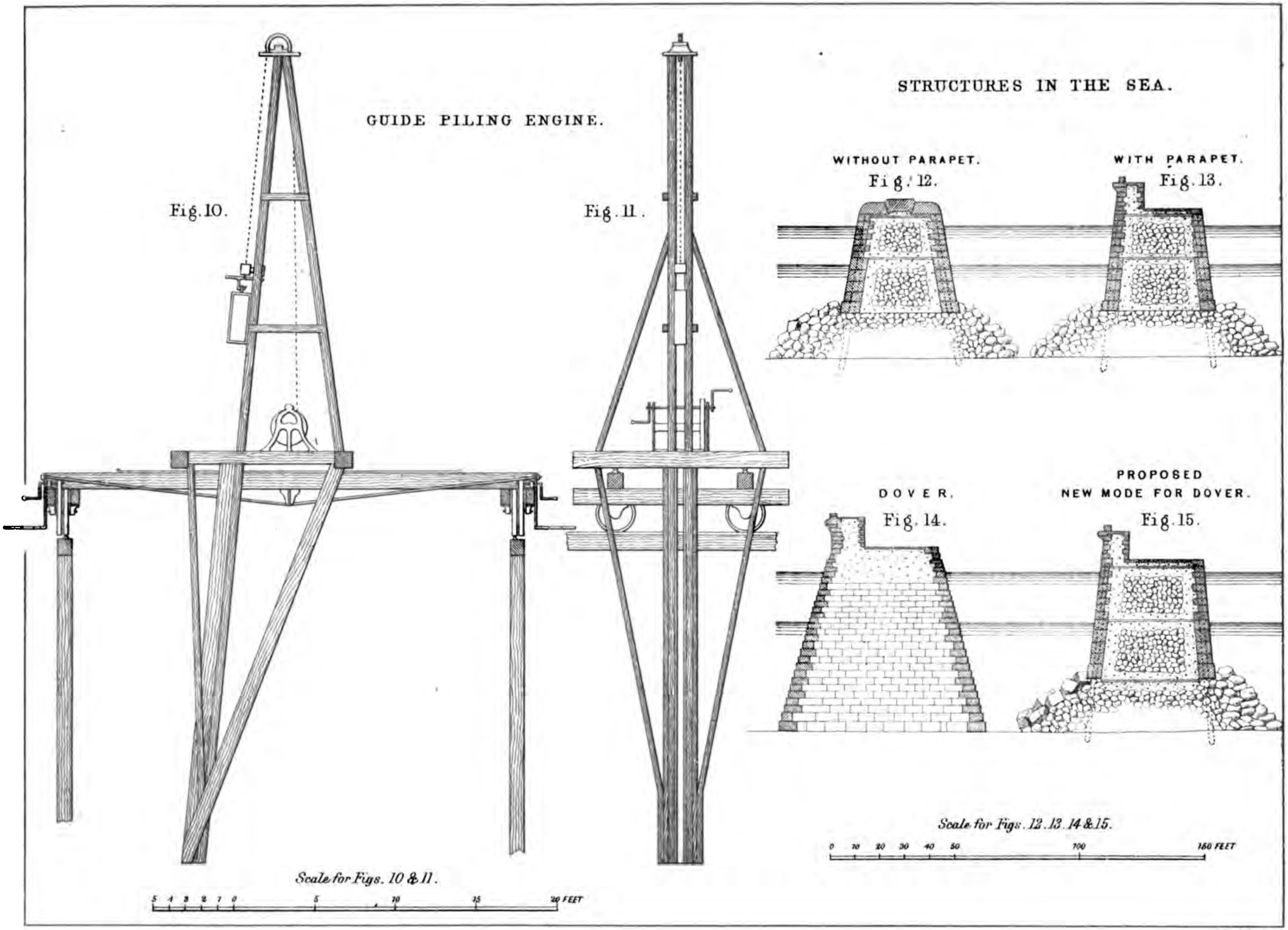
By this system the author believes great solidity and strength may be obtained, as the whole structure is bound firmly together by the iron framework, while the manner in which the stones of the facing are locked into each other, and in which the concrete will penetrate and solidify in a short time the whole mass, will realise as nearly as possible the idea, which should be the object of attainment in such structures, of a monolith, or solid rock in the bed of the ocean.

The cost of such a structure, under ordinary circumstances, and of dimensions suitable for Hartlepool, Filey Bay, or the entrance of the Tyne, may be taken at £190 per lineal yard without a parapet, and at £200 per lineal yard including a parapet wall, according to the following estimate, in which the same prices are taken as were assumed by Mr. John Murray (M. Inst. C.E.) in a previous discussion at the Institution.*

Estimate of the quantity of material in a bay of 15 feet of a breakwater, with 36 feet depth at low-water and 15 feet range of tide.

		£	s.	d.
150 cubic yards rubble in outer coating of mound	at 4s. 6d.	33	15	0
550 cubic yards rubble in body of mound (deducting one-fifth for interstices) . .	at 3s. 6d.	96	5	0
2,970 cubic feet beton blocks in facing under low-water	at 1s. 8d.	247	10	0
2,250 cubic feet ashlar facing above low-water	at 1s. 6d.	168	15	0
547 cubic yards rubble hearting (deducting one-fifth for interstices)	at 3s. 6d.	95	14	6
70 cubic yards concrete backing . .	at 10s.	35	0	0
33 square yards causeway . . .	at 10s.	16	10	0
119 cwt. wrought-iron standards (100 lb. per foot)	at 30s.	178	10	0
22 cwt. wrought-iron tranverse ties (3 inches diameter)	at 30s.	33	0	0
5 cwt. wrought-iron longitudinal ties .	at 30s.	7	10	0
Parapet.				
907 cubic feet ashlar facing . . .	at 1s. 6d.	68	0	6
9 square yards causeway . . .	at 10s.	4	10	0
30 cubic yards concrete	at 10s.	15	0	0
		£1,000	0	0

* Vide minutes of proceedings Inst. C.E., vol. xviii., p. 104.


GUIDE PILING ENGINE.
Fig. 10.
Fig. 11.
Scale for Figs. 10 & 11.
5 4 3 2 1 0 5 10 15 20 FEET
STRUCTURES IN THE SEA.
WITHOUT PARAPET.
Fig. 12.
WITH PARAPET.
Fig. 13.
DOVER.
Fig. 14.
PROPOSED
NEW MODE FOR DOVER.
Fig. 15.
Scale for Figs. 12. 13. 14 & 15.
0 10 20 30 40 50 100 160 FEET

J. R. Jobbins.

£1,000 ÷ 5 = £200, the cost per lineal yard of breakwater with parapet wall; and making deduction for parapet and addition for capping blocks, £190 per lineal yard would be the cost without parapet wall.

The blocks forming the casing under water may be either of stone or beton. When the former cannot be conveniently procured, the latter may be used with advantage, particularly as it can be so easily moulded into the required shapes, and almost of any size. The power of such blocks to resist the action of the sea for an indefinite period is now fully confirmed. These may at least be generally adopted for the inner walls of breakwaters, Indeed concrete blocks, built in the ordinary way, have been already used by Messrs. Walker and Burges at Alderney for the inner facing.

The great economy of this system of constructing breakwaters would arise from the smallness in quantity and the cheapness of the bulk of the material. The quantity of material in this breakwater compared with that in the Plymouth breakwater on the long slope principle, in the same depth of water, will be about as one to four, and the disparity of cost is not less striking, the Plymouth breakwater having cost nearly £900 per lineal yard.

In comparing with any other mode of construction the iron framework may be allowed to go for nothing, as staging of some kind must be used for the speedy and economical construction of any kind of breakwater. This framework of iron standards will not cost more than timber staging, and, indeed, far less than in cases where an immense quantity of staging requires to be used for the deposit of the enormous mass of material of long slope breakwaters such as at Holyhead; while it will be far more secure, in consequence of its inherent strength, the heavy nature of the material, and the small surface presented to the action of the waves. The buoyancy of timber staging is an element which causes its own destruction, as is exemplified at Holyhead, where it is admitted that for every piece of timber another piece is required to make up for the loss.

Another important advantage is the great speed with which it may be constructed, from the mass of material being of a nature easily deposited, and from the facility with which operations may be carried on upon a long stretch of the work at one time. In situations where the materials for the construction of ordinary breakwaters cannot be obtained, the advantages of this system would be still more striking. Dover may be taken as an example, there being no stone in the neighbourhood suitable for depositing 'à pierre perdue,' or building vertically in the usual modes of construction. By the system proposed the harder chalk from the cliffs, and shingle, could be used for the hearting, as in a structure so firmly bound together these materials concreted with beton would serve the purpose quite as well as any other. In forming the rubble mound, the example of the French engineers might be followed with advantage by forming the core of smaller and inferior materials, and for this the chalk and shingle would be quite suitable. This would be protected by a thick layer of rubble, and on the seaward side by a layer of concrete blocks, of such a size as would not be disturbed by the sea. The vertical superstructure would be constructed of chalk or sandstone rubble, concreted by beton for the hearting. A breakwater upon this construction, shown in section at Fig. 15, Plate 15, the author estimates could be built at Dover for £290 per lineal yard. The present breakwater for the same depth of 45 feet at low-water is contracted for at £1,245 per lineal yard, so that there would be the enormous saving of upwards of one million and a half sterling per mile. The difference in the cost of construction, vast as it is by this system, is not the whole saving, as the time occupied is an important element, affecting the final course of such a work, the interest on the outlay being lost until the harbour becomes available. There can be no doubt of the solidity and durability of the Dover breakwater, but considering its enormous cost, and the distance into the future before its completion will render it available for commercial or for war purposes, the wisdom of prosecuting it upon the present mode of construction may be well called in question. Upon the construction proposed, the breakwater could be completed, and be available as a harbour of refuge for the naval and commercial fleets of the country in less than five years, at a cost of a little over £1,000,000.

Breakwaters and piers have been frequently made of timber framing and casing, confining a mass of rubble. Extensive piers on this principle are in existence at Boulogne, Calais, Dunkirk, and other ports; but it is evident that such a system, from the timber being exposed and the consequent want of durability, and from their liability to sudden destruction when once the casing gives way, must prove very expensive in the end. This system has been revived, though upon more scientific principles, by Mr. Abernethy, M. Inst. C.E., and Mr. Michael Scott, M. Inst. C.E. In these plans, a structure, composed of a casing of timber, is formed of timber frames, standards, or piles and planking, and this casing is afterwards filled with rubble. But as the casing cannot be expected to possess much durability, it is proposed subsequently to enclose this structure by solid walls of masonry or composite blocks, for which the first structure will afford a convenient and substantial platform, for bearing the rails and cranes necessary for executing this part of the work. There are two distinct operations necessary, therefore, to complete the work upon this mode in a permanent manner: first, the formation of the inner structure with its timber casing; and, second, the formation of the outer structure, for the purpose of making a casing of a durable character. The economy of making breakwaters of a durable construction on these modes has not been fully made out, chiefly arising from the great quantity of timber required, and the necessity of employing two distinct casings, one of which must be superfluous.

The system which the author has proposed will, he thinks, secure all the objects which appear to have been aimed at by these plans, but with greater simplicity and economy. It is not essential that the standards employed in the system proposed by the author should be of iron, as they may be of timber, but enclosed, as has been already described in the case of iron standards, in a casing of blocks of stone or of beton. The author, however, would not recommend this, except for small piers, or breakwaters where great economy is necessary.

Application to the Foundations of Marine Fortifications.

The general application of steam to ships of war, the improvements in artillery, by which the range and weight of projectiles have been vastly extended, and the system of coating ships with defensive armour, have entirely changed the relations of works of defence on shore to those of offence from sea, and rendered the supervision of the system of fortifications, which defend the naval arsenals and seaports, a question of vital moment. The present defences have been found to be quite inadequate to cope with the new forces which can be brought against them, and in particular a necessity has been felt for the construction of advanced works, which shall keep the enemy without the range of bombarding the places they are intended to protect, or at least subject them to severe punishment while attempting it. In some cases, these can only be constructed in the sea, and in others this is the most effective situation for them. It is in this way that Cronstadt is protected, and it forms an important part of the general scheme of the new works for the defences of Plymouth and Portsmouth. There are many considerations that will render sea-forts of great value, which need not to be entered upon in this place. Suffice it to say, that it is probable the use of such advanced works will be much extended, and many situations could be pointed out where forts could be more advantageously placed in the sea than on land, for the protection of seaport towns. The difficulty, however, in the way of executing such works, is the expense and delay in constructing the foundations. The author is of opinion that the principles already described for works of a different nature, would admit in this case also of successful application for the works under low-water level. The casing might be of granite, or the greater part of large concrete blocks, capped near the low-water line, where exposed to shot, by a masive blocking course of granite. The manner in which the filling in of concrete in the interior would set in a solid mass, and in which the whole structure would be bound together by the iron standards and tie-rods, would, the author apprehends, form as efficient a foundation for the purpose as could well be devised, while the rapidity and economy with which such a work could be put down would certainly be advantageous.

In developing the foregoing system for constructing the submarine works of breakwaters, piers, quay walls, lighthouses, fortifications, and other similar structures, it must not be understood that it is advocated as being applicable in all cases, as the mode of construction of any engineering work must be determined greatly by local circumstances. But the author considers that it will admit of general application, and that the following advantages may be fairly claimed for it:—Great economy, combined with strength and durability; facility and rapidity of execution; adaptability to situations where the present modes are inapplicable.

It is to be expected that there will be considerable doubt and diversity of opinion regarding the various operations involved; such as the accuracy with which the guide-piles or standards can be driven, the facility with which the stone facing can be put in place, or the depositing and setting of the concrete in open sea-water; but it must be recollected that all these have been tested and found successful in works upon a large scale at Greenock.*

The various examples which have been given, to show the different applications of this system, must be merely understood as intended to illustrate the subject generally, as, of course, the details will admit of variation, according to the views of different engineers.

NOTE.—Sections of the breakwaters at Dover, Alderney, Plymouth, and Portland, will be found at page 229, vol. xxii. of this Journal; and sections of the Digue at Cherbourg, the moles at Marseilles, Algiers, Cette, &c. are given at page 293 of the same volume.

INSTITUTION OF CIVIL ENGINEERS.

April 25, *May* 2.—The paper read was "*On Uniform Stress in Girder Work; illustrated by reference to two bridges recently built.*" By CALLCOTT REILLY, Assoc. Inst. C.E.

This communication was suggested by a previous discussion at the Institution, when Mr. Phipps, M. Inst. C.E., condemned the trough-shaped section, commonly adopted for the top and bottom members of truss girders, because the intensity, per square unit, of the stress upon any vertical cross section, was necessarily variable, when the connection of the vertical web with the trough was made in the usual manner. In the construction of the iron work of the two bridges under consideration attention was invited, chiefly to those details which were designed with the object of carrying out, as nearly as possible, in every part of the girders, the condition of uniform stress.

After alluding to the distinction drawn by Prof. Rankine between the words "strain" and "stress," and to his definition of "uniform stress," in which the "centre of stress" or "centre of pressure" must be coincident with the centre of gravity of the surface of action, and of "uniformly varying stress," when the centre of gravity deviated from the centre of stress in a certain known direction, it was remarked, that the failure of any member of a girder would begin where the resistance to strain was really least, that was where the intensity of the stress was greatest; from which it followed, that the opinion which upheld as right in principle the trough-shaped section, as applied in the usual manner, must be a mistake. And moreover, every form of section of any member of a girder, or other framework, which did not admit of the approximate coincidence of the centre of stress with its centre of gravity, was liable in degree to the same objection.

The two bridges illustrated different conditions of loading; one carrying the platform on the top, the other having the platform between the main girders near the bottom. Both were of wrought-iron, and both exhibited an economy of material in the main girders that, so far as the author was aware, was not common, at least in this country. In order to determine the causes of this economy, a comparison was made with two other forms of truss more generally adopted. In one bridge, over the river Desmochado, on the line of the Central Argentine Railway, the pair of trusses, 93 ft. 4 in. span between the centres of bearings, was designed to carry, in addition to the fixed load, a moving railway load of 1 ton per foot of span for a single line of way, with a maximum intensity of stress of 5 tons per square inch of tension, and of 3¼ tons per square inch of compression; and the total weight of wrought-iron in the framework of the pair of trusses was 18 tons. The cast-iron saddles, rivetted on at the ends, weighed 9 cwt.; if these were included, the weight of iron both wrought and cast, in the pair of trusses, was under 4 cwt. per lineal foot of span.

The other bridge, over the Wey and Arun Canal, on the Horsham and Guildford Railway, was 80 feet span between the centres of bearings; it was designed to carry, in addition to the fixed load, a moving load of 1·875 ton per foot of single line of way, at the same maximum intensity of stress as in the other case; and the total weight of wrought-iron in the pair of trusses was 20 tons 18 cwt. The cast-iron saddles weighed 5¼ cwt. each; bringing up the weight of both wrought and cast iron in the pair of trusses to 5¼ cwt. per lineal foot of span. This weight was greater than in the first bridge, although the span was less; but the intensity of the moving load was 87½ per cent greater, and the roadway lying between the trusses instead of on the top, its weight was necessarily much greater. The cross girders were also heavier, each being adapted to support, separately, the heaviest load that could be brought on by a driving axle weighted with 16 tons; the moving load thus brought upon each cross girder, and to which its strength was proportioned, was 18 tons, equal to 2¼ tons per foot of span of bridge.

The particular form of truss chosen for these two bridges was that extensively known in the United States as the Murphy-Whipple Truss. Each of these trusses was minutely compared, according to the plan adopted on a previous occasion by Mr. Bramwell, M. Inst. C.E., with two equivalent trusses of the types generally used in this country; viz., the Warren truss, with bars making an angle of 63° 26′ with the horizon, and the simple diagonal truss with two sets of triangles, the bars crossing each other at the angle of 45°;—the various circumstances of ratio of depth to span, which was as 1 to 10, and of application and distribution of load, and consequently the number and position of the loaded joints, being common to the three trusses.

The details of the comparison were fully given in the paper, and the proportionate results arrived at in the two cases were exhibited in the following tables, relating to the trusses of the two bridges, contrasted respectively with the other equivalent trusses:—

Bridge No. I. with Load on the Top.

	No. 1. Murphy-Whipple Truss.	No. 1A. Warren Truss.	No. 1B. Diagonal Truss.
Theoretical weight	250	237·5	227
Weight of transverse stiffening to struts	17·4	29·2	42·2
Excess of practicable minimum over theoretical minimum ...	6·18	11·5	31·6
Total weight, exclusive of joints and packings	273·58	278·2	300·8

From this it appeared that the least practicable weight of No. 1 truss was less than that of No. 1A by only 1·7 per cent. It might, therefore, be said that, practically, the two trusses were equal in point of economy; and that there could be no motive for preferring one to the other, except such as might arise from considerations of workshop convenience and facility of construction. The advantage, in point of economy of weight, of No. 1 over No. 1B, was more decided, being 10 per cent.; sufficient it was submitted, speaking generally, and without denying that special circumstances might in particular cases justify a choice of the heavier truss, to entitle No. 1 to a preference over No. 1B.

Bridge No. II. with Load on the Bottom.

	No. 2 Murphy-Whipple Truss.	No. 2A. Warren Truss.	No. 2B. Diagonal Truss.
Theoretical weight	237·8	237·5	228
Weight of transverse stiffening to struts	6·6	16·1	26
Excess of practicable minimum over theoretical minimum ...	11·98	13·42	32·82
Total weight, exclusive of joints and packings	256·38	267·02	286·82

It thus appeared that No. 2 truss was lighter than either of the others by 4·15 and 11·87 per cent respectively.

With regard to the peculiarities of detail of the two bridges, it was remarked that, in order that the stress might be uniformly distributed over the surface of any cross section of either "boom," it was necessary that the two halves of the double web of each truss should each support exactly one half the load upon that truss. This, it was urged, could not be realised by the ordinary modes of fixing the cross girders; but, in the cases under consideration, it was arrived at by supporting the cross girders in the middle of the width of the truss. Thus, in Bridge No. I., each cross girder rested upon a light cast-iron saddle, or bridge, which spanned the width of the top boom, and had its bearing partly upon the top edges of the vertical struts, and partly upon rivets passing through it, the struts, and the vertical side-plates of the top boom; in such a way that the line of action of the vertical force, transmitted from the cross girder to the truss, coincided exactly with the vertical centre line of its width. In Bridge No. II. a different arrangement was necessary. In that case each vertical strut consisted of two pairs of angle irons, separated, in the plane of the truss, by a space just wide enough to permit the end of the cross girder to pass in between the pairs. At the same level as the cross girder, a plate was rivetted to each pair of angle irons; and to the centres of these plates the cross girder was also rivetted, so that the weight was equally divided between the four vertical angle irons, and the resulting stress was equally distributed between the two halves of each boom. In both bridges, the centre lines of the vertical struts, the diagonal ties, and the top and bottom booms, intersected each other at the centre of gravity of the group of rivets, which attached each strut and tie to the boom, and, in order to satisfy the condition of uniform stress, all the centre lines were axes of symmetry. In the top booms of both bridges, a section had been adopted which was believed to be new. It was somewhat like an elongated capital letter H, or like a common plate girder placed upon its side; the horizontal web, or diaphragm, being only sufficiently thick to ensure lateral stiffness. In this section all the centre lines were axes of symmetry, and consequently intersected each other in its centre of gravity; and the horizontal axes were easily made to intersect the centres of gravity of the web joints. The chief mass of metal was also placed immediately contiguous to the bars of the web, which transferred the stress to the boom,—instead of being at some distance from them, as in the trough-shaped and T-shaped form of boom. The material was likewise disposed in the best possible manner for resisting vibration; while this section gave complete facilities for examination and painting. The ends of each truss rested upon hinged bearings, by means of cast-iron saddles riveted to the junction of the endmost bars of the truss, rollers being provided at one end.

The means adopted, in the design of these girders, to obtain the utmost economy of weight, consistent with moderate economy of workmanship, were—the closest practicable approximation of the average strength to the minimum strength; the observance throughout of the condition of uniform stress, in order that all the compressed members might be trusted with the least possible weight of stiffening; the preference of rivetted web joints to those formed by single pins; and such an arrangement of the rivetting, that every bar or plate subject to tension should have its whole width, less the diameter of only one rivet-hole, available to resist the tensile force applied to it.

Lastly, the author demonstrated the true value of the condition of uniform stress, by an exact comparison of the state of a bar of the top boom of the truss of Bridge No. II., when under uniform stress, with that condition of unequally distributed stress that would occur, if the boom had a suitable trough-shaped section of equal area, breadth and depth, and therefore of equal nominal value; the elasticity of the material being assumed as perfect. The first case considered was where the stress was uniform in intensity, and the second in which the stress was unequally distributed. The final result was denoted by the equation $p=p_0 \pm \frac{x\ L\ P}{I}$; and applying this formula* to the case of the trough shaped section of boom, supposed to be equivalent to the H-shaped section actually used, the following was obtained:—The area of section was exactly the same, being 36·17 square inches. The inside depth of trough, 10 inches, would permit precisely the same disposition of the rivets in the web joint, so that the centre of pressure was situated at the same perpendicular distance, 5 inches, from the lower edges of the trough, as from the edge of the H-shaped section actually used. The centre of gravity was found to be situated at 8·088 inches perpendicular distance from the lower edge of the trough, and 2·537 inches from the top edge. The magnitude of the total stress upon the section was 125 tons. The uniform intensity of this stress was 3·45 tons per square inch; and the moment of inertia, with respect to the axis, was 336·892. From these data the greatest stress was found to be 12·717 tons per square inch at the extreme edges or corners of the sides, and the least intensity 0·544 tons per square inch along the extreme bottom of the trough. In this result the effect of flexure was purposely omitted.

In summing up the conclusions sought to be established, it was submitted that:—

1. A comparatively small deviation of the centre of stress, upon the cross section of any bar, of any piece of framework, from the centre of gravity of that section, produced, within the limits of elasticity, a very great inequality in the distribution of the stress upon that section.

2. If it were conceded that the real strength of every structure was inversely proportional to the greatest strain suffered by its weakest member, then the existence of this unequal distribution of the stress must be detrimental to the strength of any structure in which it existed, and which had been designed on the supposition that the mean intensity of the stress upon any bar was necessarily a correct measure of its strength.

3. There was no practical or theoretical difficulty in designing a truss or girder, in which the stress upon every cross section, of all the important members at all events, should be absolutely uniform.

4. The condition of uniform stress was perfectly consistent with the utmost economy of material in the structure to which it was applied.

May 16.—The paper read was "*On the Maintenance of Railway Rolling Stock.*" By EDWARD FLETCHER.

This communication related to the rolling stock belonging to the North-Eastern Railway Company, the statistics of which was comprised in twenty-nine tables, made up at annual periods extending over thirteen years, from 1852 to 1864 inclusive, showing the total number of the different descriptions of stock, and the average age of every class, at the end of each year.

The rolling stock was embraced under four distinct heads, Locomotive Engines, Carriages, Merchandise Wagons, and Chaldron Coal Wagons; the carriages and merchandise wagons being again subdivided into separate classes, of all of which a summary was given. The tables had been arranged with the view of showing, in a comprehensive form, the age of the different classes of stock, and the average of the whole. And it was submitted, that if the average age of all the stock did not exceed one-half the number of years which might be found by experience to be a fair average of the existence, or life, of the stock, then that justice was done to the stock in maintenance. Another object of these tables had been to show what per-centage the annual expenditure in maintenance bore to the first cost of the stock. It was believed that if these, or similar, tables were kept up with care, they would in a few years be the means of affording to the directors of any railway company good data for checking the annual expenditure, and for forming a correct opinion as to the sufficiency or insufficiency of the maintenance. The table showed the cost of maintenance of each vehicle per annum; and in the case of locomotive engines, the cost per mile run.

With regard to the ultimate age, or life, of rolling stock, the author was of opinion that the improved rolling stock of the present day, built of carefully-selected and well-seasoned timber, and materials of the best quality—superior as it was in all respects to that built twenty years ago —might be fully calculated to have a life of from twenty-five to thirty years; assuming always that the stock was of such a character that it would not be necessary to break it up on any other ground than that of decay. It was also to be remarked that, on all large railways, the quantity of rolling stock was always increasing, the result of which was to keep down the average age of the stock; and having a large amount of new stock, on which there was little expenditure for some years, the per-centage of outlay was proportionately diminished. Making allowances on these points, the conclusion was arrived at, that carriage stock might be fully maintained by an outlay of about 12 per cent. on its cost, wagon stock by an outlay of 6¼ per cent. and locomotive stock by an outlay of 12½ per cent. The chaldron wagon stock, which was peculiar to the north of England, generally had cast-iron wheels, was without springs, and was subject to great breakage by inclined planes and other hard usage; so that, whereas the general wagon stock only cost 6¼ per cent. on its first cost for maintenance, the chaldron wagon stock cost 17¼ per cent. This stock was by degrees being replaced by 8-ton wagons of superior construction. An 8-ton coal wagon would cost £90, and three chaldron wagons, to carry the same quantity of coals, £75; but the cost of maintenance in the first case would be only £5. 10*s*., whilst in the second it would amount to £13, showing that the superior wagon was the cheaper one of the two.

The number of locomotive engines belonging to the company at the end of 1864 was 504, and their average age was 12·48 years. Assuming that the duration, or life, of an engine was twenty-five years, then the company should have been rebuilding at the rate of twenty engines annually, to be paid for out of revenue, in order to keep the stock up to its original value; but the table showed that for the last five years an average of only eleven engines had been rebuilt, including under this head only those which were entirely new, and of a different class when rebuilt. But taking into account the engines of the same class which had been so treated, the total number reconstructed had been twenty per annum. The principal part of the engines so altered during the thirteen years from 1852 to 1864 were those which were old when they came into the possession of the company.

The following statement showed the total number of the different descriptions of stock, and the average age at the end of the year 1864; also the average cost of repairing per vehicle per annum, and the percentage of repairs, and of rebuilding on the first cost, for the thirteen years:—

Description.	Total number.	Average Age.	Cost of repairing and rebuilding per vehicle per annum.	Per centage of repairs and re-building on total cost.	Per centage of rebuilding on total cost.	Cost per mile for repairing and upholding.	Cost per mile for extraordinary repairs, included under "repairs and upholding."
		Years.	£ s. d.			d.	d.
Locomotive engines ...	504	12·48	...	12·55	...	2·95	1·92
Carriages ...	1370	9·75	22 0 9	11·26	4·46	...	...
Wagons ...	17429	10·31	4 8 4	6·39	2·89	...	...
Chaldron coal wagons ...	11872	...	2 15 0	17·42	...	...	...

The communication was accompanied by a very elaborate series of tables.

* In this formula, p is the intensity of the stress per unit of area at the distance x from the neutral axis of the stress, which intersects the centre of gravity of the section. p_0 is the intensity of the stress considered as uniformly distributed over the surface of section,—that is the total stress P upon the entire surface of section divided by the area of that surface. L is the perpendicular distance of the centre of pressure from the neutral axis, and I is the moment of inertia of the surface with respect to that axis. x is + or − according as it is measured on one side or the other of the neutral axis.—C.R.

THE INSTITUTION OF NAVAL ARCHITECTS.

Session 1865.

The Institution of Naval Architects held its Annual Meetings at the hall of the Society of Arts, London, in April last. Sir J. S. Packington, Bart., M.P., D.C.L., the President of the Institution, occupied the chair, and opened the proceedings with an address, in which he congratulated the members upon the complete and successful establishment, last November, of the Government School of Naval Architecture, and upon the liberality and promptitude with which the Government aided the views and wishes of this institution in the matter.

The proceedings of this session were extended over three days, and several valuable papers were read, of which the following are abridgements:—

On an Investigation of the Stability of H.M.S. Achilles, by Nathaniel Barnaby, M.I.N.A.

This was an account of an experiment performed at Keyham, under the author's superintendence, to ascertain the stability of H.M.S. Achilles, by determining the position of her centre of gravity. It was found that this could not be done without the introduction of 100 tons of iron ballast, because no variation which could practically be made in the ship's weights without this would have given a sufficient inclination to afford trustworthy results. Care was taken so to place the ballast, in six separate batches, three on each side, as to correct the trim, so that the previous calculations as to the position of the centre of buoyancy and the metacentre might remain unimpaired. The inclination was measured in the three hatchways, each of them being fitted with a straight batten, 20 feet long, and with a cross-batten at the foot, with a plumb-line. The operation commenced at about half-past five, by plumbing the ship upright, a slight list to port being duly noted, and a correction made on account of one of the boards not being quite vertical, so that the plumb-line gave a false reading. The reading off was performed by two men at each board, with an inch decimal scale. The distances from the centres of gravity of the piles of ballast to the middle line of the ship were then taken. The middle pile of ballast was then removed from port to starboard and the readings noted. The foremost pile was then moved across, and the readings again noted. It was not found necessary to remove the after pile. The third trial consisted in bringing back to its former position the ballast removed in the first trial, and then again reading off the inclination. The fourth trial consisted in removing the remainder of the ballast back, and a further trial repeated the experiments to port instead of to starboard. At the end of the trials the ship was then found to have exactly resumed her original position. The mean result of the experiments, which occupied exactly five hours, gave the height of the centre of gravity as 2·556 feet below the metacentre, and almost exactly in the plane of flotation. Making the correction due to the effect of the ballast not strictly representing the weight which she would carry when in sea-going trim, Mr. Barnaby found that the position of the centre of gravity, when the ship was fitted for sea, would be 3·088 feet below the metacentre, and as her load displacement is 9484 tons, the measure of the stability in foot-tons would be 29,287.

Mr. Barnaby then discussed the effect of letting water into the largest compartment of the ship. He found that this would increase the draft by 0·2 feet, and the displacement by one-tenth, but that it would raise the centre of gravity of the ship 5 inches, and reduce the stability by one-seventh.

On the Mechanical Principles of the Action of Propellers, by W. J. Macquorn Rankine, C.E., LL.D.

After remarking that the ordinary theories, based upon the assumption that the reaction of a paddle-float or screw is equivalent to the resistance of a surface of the same size and figure advancing through the water, lead to results very much in defect of the actual performance of these propellers, Professor Rankine pointed out that the true condition of propelling instruments is different, seeing that the propeller is continually laying hold of a series of new masses of water, so that the quantity of water on which it acts in a given interval of time depends mainly on the speed of the vessel. Mr. Rankine remarked that, the only previous author who noticed this fact seems to have been Mr. Bourne, who, however, did not work out the consequences. The object of the paper was to point out what, in the author's view, appeared to be the correct theory of the action of propellers, in a shape adapted for practical application, and to illustrate it by examples founded on actual ships—the Admiral for feathering paddles, and the Warrior for the screw. The whole of the mathematical investigations and numerical calculations were added in an appendix, the body of the paper containing an account of the principles. Throughout the greater part of the investigation one constant only is taken from experiment, viz., the mass of a cubic foot of sea-water, being its weight in pounds divided by the accelerating effect of gravity in a second. In that part of the investigation which relates to the friction of screws, one more constant only is taken from experiment, viz, the co-efficient of friction of a disc rotating in water.

The following general results with regard to the efficiency of propellers, neglecting friction, were stated to be applicable to all kinds of propelling instruments:—1. When the propeller works in previously still water, there is a loss of work simply proportional to the slip of the propeller. 2. When the propeller works in water previously set in motion by the ship, there is in the first place a loss of work proportional to the real slip of the propeller relatively to that moving water, and then a further loss of work proportioned to the square of the previous velocity of the water.

The probable effect of the friction of a screw was also investigated. When calculated by the formulæ obtained in the paper, the power expended in actually driving the paddles of the Admiral was found to be 77 per cent., and in driving the screw of the Warrior, $77\frac{1}{2}$ per cent. of the actual indicated power, while the efficiency of the propelling instruments themselves is found to be 0·78 for the paddles of the Admiral, and 0·773 for the Warrior's screw. Combining these data, the resultant efficiency of engines and propeller, for both ships, is found to be 0·6 or 60 per cent. of the indicated power. When the effective thrust of the paddles or screw was calculated theoretically, and compared with the resistance of the ship computed according to the principles laid down in the paper read before the Institution, by Professor Rankine, in 1864, the difference in the case of the Admiral was found to be $\frac{1}{134}$th, and in that of the Warrior $\frac{1}{70}$th part of the whole resistance; both these differences being within the limits of errors of observation. Professor Rankine added the remark, that, for such comparisons to be made in a satisfactory manner, it is necessary to have the lines of the vessel.

On Successive Integration, so as to obtain a Scale of Areas, by C. W. Merrifield, F.R.S.

This paper contained a process for so arranging the process of integration by means of ordinates, as to yield a regular scale of areas, suitable for curves of displacement, or similar purposes, without the necessity of making a separate sum of the integration up to each ordinate. Mr. Merrifield showed that the novelty of the process consisted rather in arrangement than in method, and he gave an account of the general theory by which the formula could be so extended as to give any required degree of accuracy. He exhibited a diagram containing an example fully worked, and stated his intention of adding a complete set of examples to his paper, if it should be printed.

On the Comparative Value of Simpson's Two Rules, and on Dr. Woolley's Rule, by C. W. Merrifield, F.R.S.

Mr. Merrifield began by calling attention to a remark of Professor Rankine, that Simpson's first rule applies with strict accuracy to the problem of finding the area of the cubic parabola, as well as of the common parabola. He then, by means of the calculus of finite differences, laid down a general formula for the comparison of the first and second rules, from which it appears that when both rules can be applied to the same number of ordinates, the error of the first rule is smaller than that of the second, in the proportion of 4 to 9. He inferred that the second rule should never be used, except as a mere matter of convenience, when the number of intervals happens to be odd, and also divisible by three.

Mr. Merrifield then proceeded to give some new demonstrations of Dr. Woolley's rule, and showed that it embraced the cubic paraboloid, and not only the common paraboloid, as had been previously supposed. He also indicated some modifications of it. Mr. Merrifield then proceeded to demonstrate a new formula, being an extension of the principle of Dr. Woolley's rule, to a triple integral. He showed that there was still the same remarkable simplicity to be obtained, as the final expression only involved 6 ordinates out of 27, which were required to define the integral.

Appended to Mr. Merrifield's paper was a note by Mr. H. J. Purkiss, Vice-Principal of the School of Naval Architecture, extending the principle to an unlimited number of independent integrations, and pointing out the character of the restrictions by which simplicity was gained at the expense of generality.

On the Measurement of Curved Surfaces, by means of Ordinates, By C. W. Merrifield, F.R.S.

It is difficult to give more than a very summary idea of this paper in a short abstract. Mr. Merrifield's method of measuring a curved surface depends on the common formula of the differential calculus for the element of a surface; and it is very little more than actual substitution in this formula. He first showed how to obtain the direction of a curved line by means of its ordinates, and thus to evaluate differential co-efficients, which he then combined, so as to give the element of the surface. This element was then subjected to a double integration, as if it were the ordinate of a solid of which the volume were sought, the result, however, giving the surface required. Mr. Merrifield showed that by proper arrangement, and with the help of suitable auxiliary tables, this calculation, although not short, was still well within what could reasonably be accomplished. Mr. Merrifield called attention to some books, useful for this purpose, which he had laid on the table for the inspection of members and associates.

On the Construction of Armour-clad Ships of War, by Rear-Admiral Sir Edward Belcher, C.B.

Sir Edward Belcher commenced by remarking that no reasonable thickness of iron plate, as applied at present, or proposed to be applied, for the coating of our iron-clads could be expected to withstand the heavy ordnance which it is contemplated to use for service afloat, and that our ships of war were at present so over-pressed with armour that they were virtually inefficient as rapid, handy, and active cruisers; his attention had therefore been directed to a different mode of presenting the iron works, of rendering the hull less penetrable than it is at present, and of diminishing the effect where penetration is effected, as regards splinters. Eventually, if the vessel were constructed, as regards her ribs and filling between them, on the plan proposed by the author, than she could be planked and sheathed with copper similar to our old timber-built vessels; free, moreover, from the liability of water coming at all in contact with the iron. By the practice at present pursued, the heavy and unmanageable iron plates, varying in weight from 3 to 4 tons, depended for their security of attachment to the slender framework upon through-bolts, screws, and other adaptations, all proved more or less insecure; and as yet, none of these vessels had been subjected to the reality of an action, the much more dangerous trial of grounding, or the continued concussion of severe gales loosening the fastening within as well as without—for the treatment of the targets at Shoeburyness was not to be compared with active warfare. But even there it had been proved that no thickness of metal yet presented for test had withstood the heaviest gun we even now possessed. But it was not the penetration which was most to be feared; it was the effect of the shot or shell after penetration, the yet untried difficulty of remedying the disaster resulting from one well-directed shot, and the insufficiency of the hull itself to carry the guns with that amount of armour-plating which was intended to protect them.

At the late meeting of the British Association at Bath, Sir Edward Belcher had given an outline of what he had now more fully matured. He began by assuming that as our ships were only baskets in regard to resistance to these heavy guns, we required in the first instance, irrespective of the ordnance, such shells or carcases of ships as would withstand a good fight, and be to a certain degree fit to renew action with vessels similar in force to our present armoured vessels, yet to possess greater comparative invulnerability, or, in plain terms, to possess greater adaptation for defence, and facility for remedying damages, than any we now possessed. A ship of this description demanded merely such protection up to her deepest line of flotation, or ordinary rolling angles, as would shield her machinery effectually, and, under ordinary action, be free from liability to sink within a rational period demanded to repair defects or efficiently close any specific perforations. With a hull so prepared, and decks rendered bomb-proof as regards oblique or glancing shot, the fighting batteries for guns and their crews would become but a secondary consideration, as most seamen who have seriously considered the question would probably prefer lighter bulwarks through which shot and shell could pass freely, than be subject to the frightful effect of being boxed up and mutilated by the very splinters of the plates provided for their protection.

The admiral advocated building the ship herself of such strength by the very process of construction, by placing in her framework in a peculiar manner such a proportion of iron, that iron plating should be needless, and that it would be possible to sheathe and copper as of old, and to repair damages during action with the same facility as our forefathers did. In fact, he proposed to make his frame so far shot-proof that it would not only bear comparison with the heaviest iron-clad, but would come out of action always in a condition to renew it, instead of running home to her parents here to wipe off her tears resulting from lameness. He then passed to the explanation of the mode by which he proposed to attain his object, and to compare the build of the present Warrior class, and her weight of iron. Her ribs are 2 feet asunder, and the thickness to carry the plates is but ⅝ths. She is filled in with teak, which does not, however, enter into her strength. Each cubic yard, as before stated, weighs 3123 lb. Assume 8 inches to be the diameter of the shot or shell to be used, the author gave 7 inches space between the ribs, which are to be 18 inches wide and 2 inches in thickness, cold short or case hardened on the exterior surfaces. His proposition was, to fill in with a peculiar substance, termed at present "zopissa board," possessing the same specific gravity as teak—viz., 48·—but of fourfold resistance, incombustible, protecting iron, resisting water, and finally, an absolute non-conductor of galvanic electricity. Now, as the specific gravity is the same as oak and teak, teak might be assumed for the present as the filling and backing. Therefore, taking into consideration the necessity for protecting the iron from external influence, he would first bring on 2 inches of this prepared paper (if wood be preferred after due experiment, or the zopissa board, to supersede it), and over it 4 inches of teak. Within, he would bring on two thicknesses of 3-inch paper-board to resist splinters if shot penetrated. Then followed a tabular comparison between the construction recommended by the author and that of the Warrior, and a detailed discussion of the probable effect of shot upon the two vessels. The zopissa paper-board was stated to be the invention, or rather discovery, of Colonel Szerelmey, formerly on the staff of the Austrian army. It was not a supporter of combustion; it was capable of being used in mass without waste—indeed, similar to a fusible metal. It was free from any particle of moisture; and whereas any ordinary paper would corrode iron, it, on the contrary, adhered to and formed over it a covering impervious to water. If our iron-plated ships had this substance interposed between the plates and ribs, and used as filling, the vessel would be safe, even if her armour-plating fell away. It was an absolute non-conductor of heat, cold, or electricity, and the time was, perhaps, not far distant when its use in covering boilers, steam tubes, funnels, &c., would become very general.

Sir Edward Belcher concluded with the following remarks.— I had intended, as I first stated, to have simply placed before the institution the *quasi* invulnerable and unsinkable shell of my corvette, for I would leave the protection of the men to those who think more about such matters. But I wished to add one more effort to bring all the guns to perform their duty. It is immaterial to me if you give each gun its turret—on the deck, not Coles's revolving—or bring round your connecting bulwarks for them, but I think my hearers will not fail to understand that I have so transposed Mr. Reed's rectangular box into a lozenge, that I lose no strength in whatever direction I may be assailed. I am able to show five guns ahead, astern, or abeam, by the slightest possible deviation from the course. That subject is of too much importance for a short observation. As to offence of the vessel ahead or astern, she is adapted to go over or under my adversary, and presents a sensible tool for an intelligent workman; such a tool precisely as we use in the cutting of iron. I remove my length of keel and thus facilitate turning, on the principle of the famed "mugian" (Bermudian), which has only half her deck length on her keel, and the rake of stem and stern-post at opposite angles, I propose to facilitate turning. These are secondary matters not involved in my programme. I may observe that the use of paper-board would deaden concussion considerably. I now turn to my unsinkability. It will be seen that I have added a vertical barrier to support my coal resistance backing the new construction. That a very small portion of my vessel, merely the segment of 45 degrees of her rounding, demands protection. That the coal-bunkers representing coal at 72 pounds the cubic foot cannot come into the category of bilging a compartment, to admit salt water at 64·4 the cubic foot. That the bunkers are so arranged as to keep the coal pressed home to the sides and conduct the water to the bilge. That the vertical supports resting on the floor-ends sustain the vessel completely if she grounds; and finally, if she grounds and makes a hole, these spaces under the engine-room, fore and aft, capable of being made air-tight, will, by the common-sense operation of condensing air, drive out any water that may enter, as I shall have occasion to illustrate by experiment on reading my other paper. I have already proved, as proposed by me in 1826 in Bermuda, and illustrated lately before a chairman of the London Docks, that the air in the lunge of a man can raise a model lift for a vessel, representing about 500 pounds, in about twenty minutes. That depends simply on the *modus operandi*; and I believe that with a certain amount of scientific disposition in the internal fittings of our ships, most of the bugbears of sinking could be easily overcome.

On a Problem of a Ship's Form, as presented to the Practical Builder, by Charles Lamport, Assoc.

Mr. Lamport began by remarking that the best model for a merchant ship realises the most pefect adjustment of a series of compromises, and that no one quality can be obtained in full without the sacrifice of some other. Then distinguishing the points of design, such as speed and draught, which rest with the owner, from those which rest with the ship-builder, he proceeded to point out the distinctions between mere speed through the water and making a passage, between capacity in relation to time and in relation to space only; between economy in working as a machine and profit in a mercantile sense. To ensure "making a passage" he remarked that as a rule, the form must be so modelled as to convert every motion into progress.

Mr. Lamport then passed on to the discussion of the advantage which might be taken, practically, of a ship's rolling and pitching to assist her forward progress instead of diminishing it, and gave some practical rules for the purpose. He also discussed the motion of the particles of water, both in making way for a ship's entrance and again in re-occupying her wake, and from this he drew conclusions as to the form to be given to a vessel's hull, and as to the distribution of her weights. Mr. Lamport remarked that the true direction of the particles of water in the wake of a ship and the real curve of their motion were probably mere matter of conjecture, and must be left to the judgment of the designer. The point upon which he laid most stress was, that being satisfied as to what the real cost and tendency of the water is in the ship's wake, the advantage of aiding both should not be lost sight of by the designer. Of more practical importance, because more within the limits of practical utility, he considered to be the general form of the run, so as to utilise the motion of rolling as well as the more violent one of 'scending. With regard to the bow he was of opinion that the best form of compromise warranted by all the considerations which he adduced results in what has been termed, from its vertical sections, the U bow, having a section of a parabola in the true line of resistance, viz., from any point on the bow to the surface, at an angle of 45 degrees. The author also insisted on the importance of keeping the centre of gravity of the submerged portion forward, and that of the portion above the load-water-line well aft.

Proposed Method of Bevelling Iron Frames in Shipbuilding, by W. J. Macquorn Rankine, C.E., L.L.D.

The opening or closing of angle-iron is not only difficult to perform correctly, but it strains the material very severely at the angle, and is always more or less injurious to its strength. The author suggests that the required bevellings might be given much more easily, and without the slightest overstraining of the iron, by twisting the angle-iron instead of opening or closing it. This would have the additional advantage of placing the thwart-ship arm of each frame normal to the skin, being precisely the position that is most favourable to strength and stiffness. The beam-ends and the edges of bulkheads, where rivetted to the frames, would have to be slightly bent horizontally, and the floor-plates slightly twisted so as to be normal to the skin also; and this too would be advantageous in point of strength. Mr. J. R. Napier has pointed out that the twisting should be performed on the angle-iron while straight, before bending it on the levelling plates to the required curve; and that as the twist would be very gradual, it might be given by a suitable machine to the bar when cold. The author states in a note that ribs running along the lines of greatest and least curvature of the ship's skin would be shaped by bending alone, without twisting; but that the drawing of those lines would be too difficult for general practice.

THE WEAR AND TEAR OF STEAM BOILERS.

By Frederick Arthur Paget, C.E.*

According to the published report of the engineer of the Manchester Boiler Assurance Company, forty-three explosions, attended with a loss of seventy-four lives, occurred in 1864 in this country. The engineer of the Midland Boiler Assurance Company gives the number as forty-eight, causing the deaths of seventy-five and the injury of 120 persons. These statistics are confessedly incomplete, being, from obvious causes, numerically understated. The Royal Commissioners on the metallic mines report that, in the districts of Cornwall and Devon, boiler explosions are of very frequent occurrence;† and, in these sparsely populated districts, they easily escape the public attention. Explosions, again, which only injure without killing outright, and therefore do not call for a coroner's inquest, also happen without attracting much notice. The figures cited thus understate the destruction and injury to life through boiler explosions, while only a guess can be hazarded as to the annual loss of property they cause. Each explosion testifies to the probability that a number of boilers have been prevented from exploding by mere chance, as also to much unchecked decay and deterioration, which might have been prevented by greater care and more knowledge. Besides, apart from the disastrous results of an explosion itself, the undue wear and tear of boilers means the suspension of the workshop or factory and the demurrage of the steam-vessel. With respect to the causes of explosions themselves, "there are," to use the words of the late Mr. Robert Stevenson,‡ "but few cases which do not exhibit undue weakness in some part of the boiler;" and the same opinion appears to be held by Professor Faraday.§ The opinion that an explosion is rather due to the weakness of the boiler than to the strength of the steam may in fact be said to be universal. There is, indeed, a very complex train of mechanical, chemical, and physio-chemical forces, leading to the deterioration and consequent destruction of a steam-boiler, and it is probable that no other metallic structure is subjected to such complicated conditions. The pressure of the steam and the heat of the fire produce mechanical effects, while both the burning fuel and the water react chemically on the plates, and in accordance with their varying chemical properties. Each of these agents play, so to speak, into the other's hands, furthering and quickening the other's progress. It is difficult to distinguish with strictness between the effects of each; and it is mainly for the sake of convenient examination that they can be classified into:—1. The effects of the presure of the steam; 2. the mechanical effects of the heat; 3. the chemical effects of the fuel; 4. the chemical effects of the feed-water.

The Direct Effects of the Pressure of the Steam.

In calculating the working strength of a cylindrical boiler, the plates are assumed to be under a static load, and to be submitted to a tensile strain. The former of these assumptions is seldom, and the second is never correct. There are two principal causes

* Paper read before the Society of Arts.
† Report of the Commissioners on the Metallic Mines. Presented to both Houses of Parliament by command of Her Majesty, 1864, p. xxi.
‡ Proceedings of the Institution of Civil Engineers, 1856, p. 281.
§ Proceedings of the Institution of Civil Engineers, 1852, p. 392.

that tend to exert impulsive strains on the sides of a boiler:—1. The sudden checking of the current of steam on its way from the boiler to the cylinder; 2. Quick firing, attended with too small a steam-room; and both may sometimes be found to act in combination. To the first of these causes, the explosion, for instance, of one of the boilers of the Parana steamer, at Southampton, a few years ago, has been ascribed by the Government engineer surveyor;* to the second, the explosion of the copper boiler of the Comte d'Eu yacht, in France. According to Dr. Joule, the mere dead pressure of an elastic fluid is due to the impact of its innumerable atoms on the sides of the confining vessel. When the motion of a current of steam is suddenly checked, as by the valve, in its passage from the boiler to the cylinder, its speed and weight cause a recoil on the sides of the boiler analogous to the effects of the, in this case, almost inelastic current of water in the hydraulic ram.† This action is necessarily most felt with engines in which the steam is let on suddenly, as in the Cornish and other single-acting engines, working with steam valves suddenly affording a wide outlet, and as suddenly closing. It produces such phenomena as the springing or breathing of cylinder covers, and the sudden oscillations of gauges, noticed long ago by Mr. Josiah Parkes and others.‡ Some years ago, while standing on a boiler working a single-acting engine, and with a deficient amount of steam-room, the writer noticed the boiler to slightly breathe with every pulsation of the engine. The same action has been observed by others with boilers the steam-room of which is out of proportion to their heating surface. The intensity of the instantaneous impulses thus generated would be, as Mr. Parkes observes, difficult to measure, but their repeated action must rapidly affect the boiler at its mechanically weakest points. The more or less sudden closing of a safety valve while the steam is blowing off would evidently produce the same effect; and this view is strengthened by the fact that the great majority of locomotive boilers—in which while at work there is no such sudden call on the reservoir of steam as in the Cornish engine—explode while standing, with steam up, at the stations.§ It is not denied that in the case of a locomotive the mere extra accumulation of steam, from the safety-valves being screwed down above the working pressure, will also come into play. But there can be little doubt that most boilers are subjected sooner or later, and with more or less frequency, to an impulsive load. This being the case, this consideration alone would demand a factor of safety of *six* in the designing of steam boilers. The Commissioners on the application of iron to railway structures, in their third conclusion on a mass of evidence, which has made their investigations the most valuable ever conducted on the strength of materials, say —"That, as it has been shown that to resist the effects of reiterated flexure, iron should scarcely be allowed to suffer a deflection equal to one-third of its ultimate deflection, and since the deflection produced by a given load is increased by the effects of percussion, it is advisable that the greatest load in railway bridges shall in no case exceed one-sixth of the weight which would break the beam when laid on at rest in the centre.‖

Emerson showed, more than sixty years ago, that the stress tending to split in two an internally perfectly cylindrical pipe, submitted to the pressure of a fluid from the interior, is as the diameter of the pipe and the fluid pressure. He also showed "that the stress arising from any pressure, upon any part, to split it longitudinally, transversely, or in any direction, is equal to the pressure upon a plane drawn perpendicular to the line of direction." As in a boiler the thickness of the metal is small compared with the radius, the circumferential tension has been assumed to be uniformly distributed; and the strain per unit of length upon the transverse circular joint being only half that upon the longitudinal joints, the strength of the latter has been taken as the basis of the calculations for the tensile strength of the joints. But in taking the internal diameter of the boiler as the point of departure, the internal section has been assumed to be a correct circle, which would only be practically true in the case of a cylinder bored out in a lathe, and never in that of a boiler. Two of Emerson's corollaries from his first proposition have in fact been neglected. He shows that if one of the diameters be greater than another, there will then be a greater pressure in a direction at right angles to the larger diameter; the greatest pressure tending to drive out the narrower sides till a mathematically true circle is formed. The second is that, "if an elastic compressed fluid be enclosed in a vessel, flexible and capable of being distended every way, it will form itself into a sphere."* A number of proofs can be adduced that both these influences are more or less at the bottom of the wear and tear caused by the direct action of the steam.

From 1850 to 1864 forty locomotive explosions causing a loss of human life have occurred in the United Kingdom. The Board of Trade reports in the Bluebooks presented to Parliament, and more especially those by Captain Tyler, R.E., probably form the most valuable and connected series of records extant on boiler explosions. This is more especially the case with regard to wear and tear caused by the direct action of steam unmasked by the effects of the fire, as the barrel and outside fire-box of a locomotive cannot be said to be under the direct action of the heat. Perhaps the vibration of the boiler through the motion on the line may intensify this action, but it is clear that vibration cannot be a primary cause. The majority of the reports are illustrated by careful drawings. Eighteen of the forty boilers gave way at the firebox—eleven, from the crown of the inside fire-box being blown down upon the tube plates; seven, from the shells or sides giving way. Twenty burst at the barrel; and two explosions may be ascribed to miscellaneous causes, from an originally defective plate, and from running off the line. Leaving out all those which occurred at the fire-box, as the majority of these might be ascribed to other influences than direct pressure, all the twenty explosions of the barrel could be traced either to internal furrows or to cracks, both running parallel with one of the longitudinal joints of one of the rings forming the barrel. All the joints which thus gave way were lap-joints; and the furrows or the cracks (and the former greatly preponderate in number) occur at the edge of the inside overlay, and, therefore, just at the point where the diminution of diameter caused by the lap-joint would be most affected by the pressure of the steam. (See Fig. 1, page 184.)

The plate at the channels shows distinct traces of lamination through the cross-bending, and it is probable that plate of a good material will gradually laminate, while inferior metal will crack through in much less time. Nor are these furrows found with only lap-joints. Butt-joints, with a strip inside the boiler, and thus destroying the equilibrium of internal pressure, have been found to be attended with similar furrows. Channels of exactly the same character have been observed in locomotive boilers with lap-joints, which have exploded in Germany.†

Similar furrows, again, have been noticed in marine boilers, and in old boilers generally, longitudinal furrows being of course about twice as dangerous as those appearing transversely. The smoke-box tube-plates of inside-cylinder locomotive engines have been found to be similarly influenced by the raking action of the engines, showing furrows around the cylinder flanges. A parallel case is often found in Lancashire with the end-plates of double-flued Fairbairn boilers, which may have been too stiffly stayed to the barrel. Circular furrows, caused by the confined motion of the end-plates, are sometimes found at the base of the angle-iron rings jointing the internal flues to the end-plates. But furrowing seems with no kind of boiler to be more felt than with locomotive boilers. This is due to the higher pressure, to the thicker plates causing a coarser lap, and more especially to the fact that the unstayed barrel cannot be thoroughly examined without drawing the tubes, thereby enabling the furrow to enlarge itself unnoticed.

The inside fibres of a plate bent up while cold are necessarily initially in a state of compression. When the pressure from the inside comes on, striving to form a perfect cylinder, the plate gets bent to and fro, by its own elasticity on one side, and by the pressure of the other. If the iron be brittle, it may crack

* Rudimentary Treatise on Marine Engines and Steam Vessels, etc. By Robert Murray, C.E., Engineer Surveyor to the Hon. Board of Trade, p. 74—78.

† Instituto di Scienze. Milano, 1829.

‡ Transactions of the Institution of Civil Engineers, vol. 3.

§ Reports of the Inspecting Officers of the Board of Trade, 1850—1864. (The four locomotive boilers which burst last year all did so while standing. Neither the primary rupture leading to the explosions, nor the secondary rupture caused by the explosion, took place through the rivet holes.)

‖ Report of the Commissioners appointed to inquire into the Application of Iron to Railway Structures. xviii.

* The action of a fluid pressing with equal forces in all directions can be evidently represented as to force and direction by innumerable radii of equal length led from a single point in all directions. Upon this principle may be explained the spherical shapes of soap bubbles, of the bulbs of thermometers (blown while the glass was in a plastic state), of the thin india-rubber balls, used as playthings, and which are formed by forcing air into india rubber tubes closed at one end. Gas and air bubbles in water are necessarily flattened by the hydrostatic pressure. It is upon that principle that a gun of soft ductile iron often bulge out at the breech.

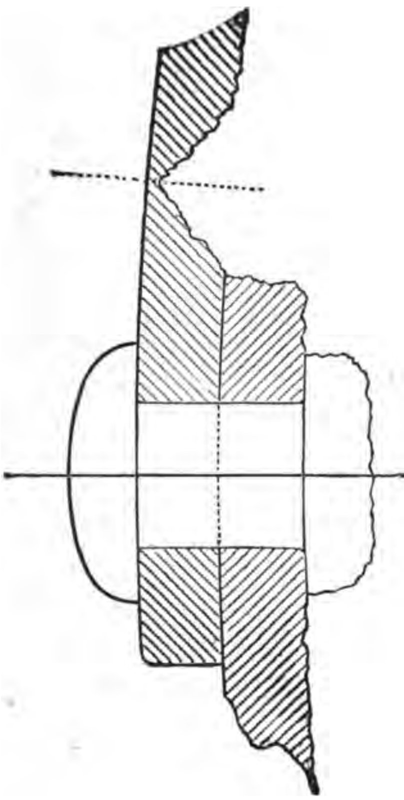
† Organ fuer die Fortschritte des Eisenbahnwesens, 1864, p. 159

right through; if ductile, the outside fibres gradually lose their elasticity, and, necessarily aided by other causes, crack away. This action is progressive, and probably very rapid towards its later stages. Once a weak place formed itself, it would have to do more and more of the work. Even when pulled by the direct tension of the testing machine, a lap-joint behaves in a somewhat similar way. For instance, a half-inch lap, solidly welded by Bertram's process, has only half the strength of the solid plate;* while the ⅜-inch lap-weld has actually two-thirds of the strength of the entire plate.

Messieurs Jean Piedbœuf and Cie., of Aix-la-Chapelle, Düsseldorf, and Liege, who turn out annually upwards of one thousand steam boilers, use a lap-joint which probably gives slightly better results as to furrowing, while it is much easier to caulk, and must be therefore less injured by that process. (See Fig. 2.)

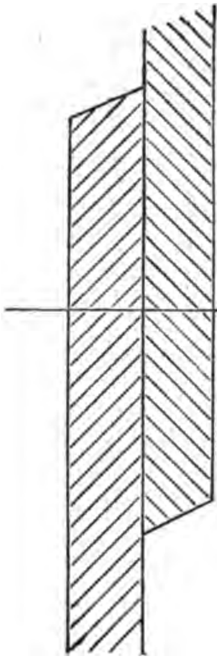
There is, however, another important appearance to be noted with respect to these furrows. An iron cylindrical vessel under

Fig. 1.



Full size cross section of the furrowed longitudinal joint in the fire box ring of a boiler which exploded at Overton Station, on the 30th May, 1864. It does not differ from other furrows.

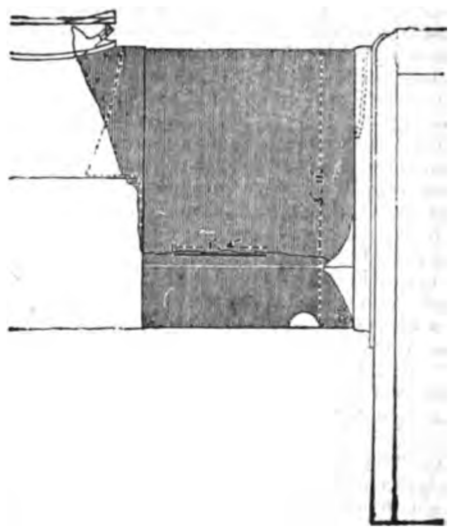
Fig. 2.



The edges of the plates are cut to an angle of 65° by means of inclined shears.

internal pressure would of course rupture long before it could assume a spherical shape, from its ranges of elasticity and of ductility being so short. But it may be said to be undergoing three distinct stresses in as many directions. There is a stress acting on the ends, and tending to rupture the boiler in two halves in a direction parallel to the axis; there is the stress which is hoop tension in a true circle, but which acts with a cross-bending strain in an ordinary boiler; and there is the stress which tends to make it assume the shape of a barrel, or to bulge it out in the centre of its length. The precise action on a material of several strains like this is a portion of the strength of materials which is still completely unknown. Its probable effects might be illustrated by the ease with which a stretched india-rubber ring is cut through with a knife, or that with which a column under compression is broken by a blow from a hammer, or by the similar ease with which a tube under tension is split by a sharp blow; in fact the operation of caulking a defective boiler under steam seems thus to often give it the finishing stroke which causes an explosion. The new boiler which burst from a defective plate at the Atlas Works, Manchester, in 1858, and that which burst through a crack at a longitudinal joint, last January, at Peterborough, both gave way whilst being caulked. This again accounts for the fact that adjacent boilers sometimes explode one after the other, pointing, at the same time, to the danger into which a sound boiler may be thrown by an explosion. Upon the same principle, it is probable that the modern guns, built up from strained rings, will be easily put *hors de combat* by shot. The probability is that a number of simultaneous strains in different directions diminish the elasticity of the material that would allow it to yield in any given direction. However this may be, it will be seen that it is only the pressure on the ends of the boiler acting parallel to the axis, and tending to tear the cylinder through transversely, which bears fairly on the rivetted joint, or rather on that metal between the rivets which is left after punching. Unless the cylinder be perfectly correct inside, the circumferential strain resolves itself into cross-bending, shifting the dangerous strain from the iron left after punching to the metal at the over-lap. With respect to the stress tending to bulge the cylinder in the centre, it is clear that if we suppose a strip cut out from the entire length of the boiler, each portion of the length of this strip could be regarded as a beam under an uniformly distributed load. As however, with the lap joint, there is a double thickness of metal transversely, that joint is the strongest and stiffest portion to resist the stresses tending to bulge out the cylinder

Fig. 3.



From Capt. Tyler's report, dated 30 June, 1864, on the boiler explosion at the Overton station of the London and North-Western Railway. The plate torn off is shaded, the course of fracture on the other side of the boiler is dotted, while the furrow is shown by the thick horizontal line.

in the middle, and also to tear it into two halves. This affords some justification for the belief of old boiler-makers, before rivetted joints were tried under a direct tensional load, that the joints are the strongest parts of the boiler. And, indeed, this is what we find in practice. The thinnest portion of the longitudinal furrows is generally exactly in the middle of the plate, and this is caused by the longitudinal stress, which is acting at right angles to the transverse cross-bending stress. A strip cut from joint to joint is, in one respect, in the condition of a beam supported at both ends, uniformly loaded throughout its length, and, according to known principles, therefore giving way in the middle. (See Fig. 3.)

The middle ring of the boiler which burst on the Metropolitan Railway last year, and the fragments of which were examined by the writer, also first gave way at the furrow. Captain Tyler reports that at from 16½ to 19 inches from the transverse joint, or just about the middle of the plate, there was "very little metal left holding," while it gradually got to its original thickness of ⅜-inch, as the groove receded from the centre of the plate and towards the transverse joints at each side.

‡ Recent practice on the Locomotive Engine, p. 6.

It is impossible to deny the existence of an infinite number of stresses acting on the sides of a vessel undergoing fluid pressure, producing what, for want of a better term, might be called a "bulging strain." Instances of this action may be noticed in the sketch of the leaden pipes given by Mr. Fairbairn,* which were bulged out in the middle by internal pressure, as also in the fire-box sides† influenced by the same means, and in the centre of the surface. Unaccountably enough, the effect of such a strain on the ultimate resistance, and, above all, the elasticity, of materials, has been entirely neglected by investigators, and there are no published data on the matter. The effect of the internal pressure is evidently resisted by a double thickness of plate at the joints, so that the load on the middle of a single ring may be considered as determining the weakest part of the boiler. One of the rings of the Great Northern boiler, which exploded on the Metropolitan Railway last May, had a length transversely of about (say) 36 inches from lap to lap, with an inside diameter of 45 inches. If we now suppose a strip 1 inch broad, cut from the 36-inch long plate, parallel to the longitudinal axis of the boiler, this strip is, supposing there be a pressure of 100 lb. to the square inch, uniformly loaded with 3600 lb.—equal to a transverse load of 1800. lb at the centre. Supposing the plate to form a true circle, a hoop 1 inch wide of the ⅜ plate would be subjected, circumferentially, to a tensile load of 6000 lb per square inch, while (leaving out the diminution of area at the ends through the flue tubes) each portion of the circle, about 1 inch broad and ⅜ inch thick, is subjected to a load of about 1125 lb. acting parallel to the axis of the boiler.

To construct a general rule or formula that would take into account the distorting effects of the lap or of the welt of butt-joints would be impracticable; but it is clear that the usual mode of calculating the strength of a cylindrical boiler, from the tensile strength of joints tested by weights or hydraulic pressure directly applied, is far from being correct. It is only tolerably correct with scarf-welded joints, or with butt-joints with outside welts. Even here, the hoop tension of the true cylinder is resolved into a cross-bending strain, if the cylinder does not form a correct circle internally. The usual formula would be practically correct if the boiler were prevented from altering its shape during the impulses sometimes given by the steam, and the quieter buckling action caused by the alternate increase and fall of the pressure. In fact, a boiler, like a girder, does not merely demand a high ultimate strength, but also a stiffness which is the protection against alternative strains, against buckling or collapse.

Disregarding the effects of the thickness of the material, a perfect cylinder should theoretically afford the same ultimate resistance, whether exposed to external or internal pressure. Its resistance to collapse should indeed be greater, as most materials give more resistance to compresson than to tension. This is not the case, as the distortion of form progressively weakens an internal flue, by increasing the load on its surface, while the contrary is rather the case with the boiler exposed to internal tension. Before Mr. Fairbairn showed the inherent weakness of flue tubes, their frequent explosions through collapse were ascribed to spheroidal ebullitions and other similar causes. They are now, according to the engineer of the Manchester Boiler Association, stronger than the shells, by means of the T-iron and angle-iron bands now generally used, and also by the excellent seams introduced by Mr. Adamson so long ago as 1852.‡ While T-iron and other bands could be used for the barrels of boilers not exposed to the fire, (as is recommended in France§ and by the Board of Trade Inspector of Railways), Adamson's seams reversed would probably form excellent transverse joints for a shell fired from the outside, and, with a boiler like this, thin and narrow plates could be used, affording a stronger and tighter lap-joint. With a construction of this kind, little or no deflection or bulging could occur, and the sectional area of the plate and the rings would really give the strength of the boiler.

2.—The Mechanical Effects of the Heat.

While a maximum of stiffness to the mechanical action of the pressure is required in a steam boiler, a maximum of flexibility to the irresistible mechanical force of heat is of no less importance. For instance, a great advantage of some of the forms of strengthening rings for internal flues is that they allow the use of thinner plates, together forming a structure of great flexibility to complicated thermal influences. The longitudinal expansion of inside flues like this is taken up by a slight spring or swagging at each joint, and the end plates of the shell are not unduly strained by the combined efforts of the internal pressure and the expansion due to heat. This is one way in which defective circulation, or a sudden current of cold air or of water, can act on the structure by unequally straining the plates; and although it seems probable that the effects said to have been thus produced are, to some extent, due to other causes, they point to the importance of keeping the temperature of the plates as low as possible. One protection against effects of this kind is the gradual diffusion of heat produced by its conduction to and from the different plates. It is a general belief with engineers that a pressure of steam strains a boiler more than cold hydraulic pressure, but it is unsettled as to what amount and in what exact way. The basis of an examination of the kind would have to be sought in an exact determination of the temperature of a plate which is transmitting the heat to the water, and this has not yet been determined with any accuracy. The fact is, as is remarked by M. Peclet, who has given great attention to these questions, the different phenomena involved are extremely complicated. It is clear that the plates must always be at a higher temperature than the water, as it is by the difference of temperature of the two surfaces of the plate that it is traversed by the heat. He supposes that, though the flow of heat through the plate is inversely as its thickness (while it is directly as the surface and as the difference of temperature between the outside and inside faces), yet the flow of heat would be the same through a thicker plate, from the greater difference of temperature between the two surfaces.* He does not seem, however, to be aware of the important law demonstrated by Mr. J. D. Forbes, that the conducting power of, for instance, wrought-iron, rapidly diminishes at the higher temperatures. At 200° C. it has little more than one-half the conducting power it has at 0°.† At yet higher temperatures it might probably be proved, if an applicable instrument for registering higher temperature were in existance, that the powers of conduction are still less. Some of M. Peclet's experiments also seem to be vitiated by his disregard of Dr. Joule's discovery, that water is heated by being mechanically stirred up. It is, however, certain that water can only moisten a metallic plate when at a lower temperature than 171° C. As soon as the water gets thus repelled, the heat radiated by the metal is reflected back from the surface of the liquid; the metal gets hotter and hotter, with a corresponding diminution of its conducting powers; its outside, exposed to the fire, would more or less oxidise, and with a similar result; and a like effect is produced on the inside, on the roughened surface of which incrustation would rapidly adhere, forming a calcareous coating, conducting with about sixteen times less power than iron.‡ All these tendencies are of a progressive character, leading to very high temperature in the plate, even to a red heat. This tends to explain how rivet-heads close to the fire are soon burnt away by the friction of the current of heated gases on the red-hot metal; how thick fire-boxes are sooner burnt out than lighter ones, the process being often arrested at a certain thickness; how internal flues of thick plates so often give trouble; how externally fired boilers are most deteriorated at the corners from the junction of the three plates; and similar results well known to practical men. Another proof that thin plates conduct more heat than thick plates is afforded by some experiments lately made in Prussia with two egg-end boilers, exactly similar in every respect, except that one was constructed of steel plate ¼-inch, while the other was of wrought-iron about ½-inch thick. The steam generating power of the steel boiler was to that of iron as 127·49 to 100,§ a result which can only be accounted for by the relative thickness of the plates. Thick plates are also more liable to blisters, one of which would considerably diminish the conducting power of the spot where it happened to form.

While it is certain that boiler plates can assume very high temperatures, even up to red-heat, authorities differ as to the

* Philosophical Transactions, 1858, p. 402.
† Useful Information for Engineers, 1856. Appendix xviii.
‡ Specification No. 14,259.
§ Bulletin de la Société Industrielle de Mulhouse, 1861, p 532.

* Traité de la Chaleur. vol. 2, p. 393.
† Royal Society of Edinburgh, 28th April, 1862. 'Experimental Inquiry into the Laws of the Conduction of Heat in Bars, and into the Conducting Power of Wrought Iron.'
‡ Traité de la Chaleur, vol. 1, 391.
§ Verhandlungen des Vereins zur Beförderung des Gewerbfleisses in Preussen, 1862, p. 140.

diminution of ultimate strength which is caused by heat, while its effect on the elasticity of the plate has been scarcely attended to. The experiments on the ultimate tenacity of iron at high temperatures, conducted by Baudrimont,* Seguin, and the Franklin Institute, can scarcely be looked upon as of much value, for they were made on a very small scale, and with no regard to the temporary and permanent elongations, or to the effect of heat on the elasticity and ductility.

Mr. Fairbairn† observed no effect on the strength of plate iron up to almost 400° F.; At a "scarcely red" heat the breaking weight of plates was reduced to 16·978 tons, from 21 tons at 60° F.; while at a "dull red" it was only 13·621 tons. MM. Tremery and P. Saint Brice,‡ aided by the celebrated Cagniard Latour, found that at nominally the same temperature (*rouge sombre*), a bar of iron was reduced in strength to one-sixth of its strength when cold. This is much greater diminution of strength than that found by Mr. Fairbairn. Apart from other causes, this might easily be due to the fact that incandescent iron affords a different tinge during a dull day to what it does in a clear light. In fact, the great impediment to all these investigations is the want of a thermometer for high temperatures; but M. Tremery's result is perhaps more conformable with daily experience. Mr. Fairbairn's data would show that the ultimate strength of wrought-iron is reduced to about one-half; but M. Tremery's result explains the generally instantaneous collapse of flues when red-hot, and which have been of course originally calculated to a factor of safety of six.

A most important question is the effect of temperatures, whether high or low, on the elasticity of the material—whether iron will take a permanent set with greater facility at a high temperature? These data are really more important than those on the ultimate strength, as they would show the influence of temperature on the elastic limit. Here again is a vacancy in existing knowledge, which can scarcely be said to be filled up by the few experiments of the late M. Wertheim on very small wires.§ He found, however, that the elasticity of small steel and iron wire "increases from 15° C. to 100°, but sometimes even less than at the ordinary temperature."

(To be continued.)

IMPROVEMENT OF TOWNS.

By James Lemon, A.I.C.E.

No. I.

The improvement of the Metropolis, and some of our provincial towns, has within the last few years been earnestly promoted by the several local authorities, stimulated by many valuable suggestions from various correspondents. It must be admitted, however, that in many instances the subject has not received that attention which its importance demands; and the beneficial results which have been obtained in some towns, show more forcibly by contrast the neglect in others, and the want of unanimity which is so necessary for the successful carrying out of any public work on a liberal scale.

Of the numerous works which are comprised under the title of this article, the formation of new streets may be justly considered as one of the most important; and therefore should receive the first notice at our hands. In the Metropolis some progress in this respect has been made, by the construction of the new approach to Covent-garden, called Garrick-street, and also the communication between Blackfriars-road and London-bridge, called Southwark-street. It is also contemplated by the Hampstead, Midland, North Western, and Charing Cross Railway Company, to construct a new street from Charing-cross to Tottenham-court-road, a direct route from north to south, long needed. Some few other schemes are also decided upon, such as the raising of the Holborn Valley, the improvement of Park-lane, the approach to Commercial-road, Whitechapel, and last but not least, the new street from the Thames Embankment to the Mansion House. We gladly accept these, as an earnest for the future, but how small they appear in comparison with the improvements which have been effected in Paris in a few years: although it may be urged that there were political reasons for destroying the confined narrow streets and blind alleys, and opening up the wide and magnificent boulevards; but whatever may have been the motives, the results are not only direct communication from one part of the city to the other, and the substitution of large and handsome buildings for small and dilapidated dwellings; but a steady decrease in the rate of mortality, whereas in London, there has been a considerable increase. In support of the foregoing statement, we have the official returns on the subject, by which it appears that during the years 1860, 1861, 1862, and 1863, the mortality was as follows:—

In Paris a decrease of 0·60 in a 1000.
In London an increase of 1·98 in a 1000;

and if we include the year 1864, an increase of 3·96 in a 1000; showing the superior sanitary condition of the French capital. Then, as the new sewers of Paris do not carry off the drainage from the waterclosets, the cesspool system with all its attendant injurious effects being still in operation, we may fairly conclude that the marked sanitary improvement may be traced chiefly to the abolition of narrow streets and unwholesome buildings, as before stated.

Much has been said and written upon the value of our parks and open spaces, which are without doubt a great boon to the inhabitants of large towns, enabling some of them to obtain pure air and exercise; but how many there are who never have the opportunity to enjoy them, whose life is spent in unceasing toil in crowded ill-ventilated rooms, which they do not leave until nature is exhausted, and their only desire is to obtain rest after the labours of the day, so as to fit themselves for the work of the morrow. Then how much better would it be, to allow pure air to find its way to their homes, by opening up wide and direct lines of communication and aëration, certainly one of the best means of decreasing the mortality which can be devised, as all other sanitary improvements must follow.

In the formation of new streets, many of the narrow and confined courts and alleys are swept away, loathsome and dilapidated hovels, occupied by poverty, and in many instances by crime, are exposed to view, and their inhabitants compelled to seek fresh quarters, which, if it does nothing else, breaks up old connections, and causes many to start upon a fresh and brighter career.

In a pecuniary point of view, it is to the interest of municipal bodies to take care of the health of the poor, because in the event of continued sickness they are compelled to seek relief from the parish: then certainly the readiest way to effect that object is to promote good drainage, and wide and open streets. New streets mean new dwellings, and new dwellings under proper supervision mean light and air to the occupiers, consequently by the preservation of his bodily strength the industrious labourer is enabled to support himself and family without assistance from his richer brethren.

At the present time, however, it is thought by many that the improvments contemplated in the Metropolis, by removing the dwellings of the poor, will cause overcrowding in other neighbourhoods and increased burdens upon the rates of those localities; no doubt in some instances it will be so for a short period, but it is only a question of supply and demand; already there are erected improved dwellings for the labouring classes, in which the health and comfort of the occupiers have been well studied, and which are let at less rents than many of the dilapidated hovels they have displaced. As an illustration thereof, compare those admirably constructed dwellings which have been erected by Miss Burdett Coutts, Mr. Peabody, Mr. Waterlow, and many others, with the houses upon the site of the proposed Law Courts at Carey-street, about the removal of which there has been such an outcry, and which many members of the Lords and Commons have such a great desire to preserve.

There are also workmen's trains on the London, Chatham, and Dover Railway, and we are promised dwellings for the working classes a short distance from London, and at moderate rents, including railway fare. In fact, the compulsory removal of the poor of the thickly populated districts will, in the end, become one of the greatest benefits which can be conferred on them, as it has caused men of capital to take up the subject of improved dwellings, which otherwise would, perhaps, not have been considered.

Having in the foregoing remarks endeavoured to prove the desirability for the formation of new streets, your correspondent

* 'Annales de Chimie et de Physique,' 3, s. 30, p. 304, 1850.
† On the Tensile Strength of Wrought Iron at Various Temperatures. Reports, British Association, 1856, p. 405.
‡ Annales des Mines. 2 serie. Vol. iii, p. 513.
§ Comptes Rendus, xix., 231.

begs to submit a few notes upon the mode and principles of their construction, and the means of widening and improving the present roadways.

No road or way for the purpose of carriage traffic can be formed within the Metropolis of less width than 40 feet, without the consent of the Metropolitan Board. But is this sufficient? Would it not be wise to amend this regulation by enacting that all new streets should be equal in width to the height of the proposed buildings, measured from the footway to the highest part of the roof of such building? This would, perhaps, be objected to by some persons, on the score that it would limit the height of the buildings, and not increase the width of the streets, but I think it would be found that such would not be the case. For example the value of building land is estimated by its frontage, and the price per foot frontage on a building lease is in proportion to the class of building and the locality, consequently it is to the interest of the lessee to erect that class of house which will produce the highest rent, and for the lessor to form the street of sufficient width to command the largest class of building, with reference to the locality, and thereby obtain the highest possible ground rent. Under the existing law, new streets are kept to the minimum width of 40 feet, and lofty buildings are erected, to the great loss of light and air, whereas if the freeholders were compelled to lay out their streets as proposed, they would sooner increase the width than suffer the loss of revenue, from being debarred from letting their land for the erection of a superior class of buildings.

As regards the improvement of existing main thoroughfares, it is desirable that a general scheme for the ultimate widening be prepared and approved for the Metropolis, and also for provincial towns, and that no buildings should be allowed to be rebuilt beyond such improved line of frontage, the owners being compensated for the loss of space by setting back the said buildings. The Metropolitan and district boards have power to do this under the Metropolis Local Management Act, and the Local Boards of Health under the Local Government Act, 1858. The work of reconstruction would necessarily be slow, but still it would be progressive, and not as at present deferred until large and costly buildings are erected immediately in the line of the proposed improvements, when from the increased cost they are finally abandoned.

The ultimate working width of any street, for through traffic, is only that of its narrowest part, the increased width of any particular portion acting only as a lay-bye for stoppages, or affording greater facilities for local traffic. For example, of what avail for through traffic is the great width of Holborn, when it is impeded at Middle Row and at Newgate-street. The same remark as to inequalities of width may also be made as regards the Strand, Chancery-lane, and many of the main streets in the Metropolis.

As regards uniformity of width, the new streets which have been lately formed by the Metropolitan Board of Works are certainly much to be commended; but in respect to Garrick-street, a better effect would have been produced if it had been designed 10 feet wider, as from the loftiness of the buildings it looks narrow. The same defect is not so apparent in Southwark-street, it being 20 feet wider; but if the example as to height set by the architect of the hop warehouses, on the south side, had been followed in the design of the other buildings, the open appearance it now has would have been lost.

In laying out new streets through the thickly populated parts of a large town, it is extremely desirable that sufficient property should be purchased on each side, that the entire frontage may be available for the erection of buildings which the locality will command. This principle has been lost sight of in forming the new street at Southwark: there we have an extremely valuable frontage obtained at great cost, which in some parts, from the want of depth and the unsuitable form of the ground, is almost entirely useless for building purposes. It will without doubt be urged, that the board only schedule sufficient property for the purpose of forming the street, but it is an extremely narrow-minded policy, it is what an individual looking towards a good investment for his capital would never think of doing, then why a different course should be adopted by a public body, it is extremely difficult to state.

(To be continued.)

SILT TRAPS ON THE DEHRA DOON CANALS, INDIA.

By R. E. Forrest, *late Superintendent Doon Canals.*

(With an Engraving.)

Silt and sand are the great enemies of all irrigation canals. As might have been expected, this subject has largely engaged the attention of the Italian engineers. Some of their most interesting writings treat of the depositions of silt and gravel, and of their efforts to exclude or get rid of the latter, with which they had chiefly to deal.

"Some authors have proposed expedients to prevent any sort of gravel from entering canals. Eustace Manfredl, in treating of the means of drawing from the Lebir a fixed branch from below Porto Nuovo to below Perugia, proposed the construction of a weir, which in consequence raised the surface of the water eight Roman palms. He directed also that the sill of the entrance at the head of the canal should be five Roman palms below the heightened surface of the water, so as to retain in the canal the sufficient depth of five palms of water, and by the three redundant palms to prevent the introduction of any pebbles. Again, Belidor, in the sixth chapter of his book, has suggested the idea of receiving the waters into a great reservoir, in which they might deposit their gravel before they entered the canal; but although this plan has been practised in the famous canal of Languedoc, it is always liable to the objection that it is extremely difficult and expensive in the execution, and never applicable to any case in which it is necessary to draw a fixed channel from a great river running between mountains."*

The above was for excluding gravels; and to remove them—"They have sufficiently provided for the clearing out of the beds in the upper trunks of these two canals, where stones and gravel are brought down in great abundance with the stream, by placing in them a number of discharges sufficient for the purpose, called bottom or ground sluices. This sort of outlet should be constructed in the bank of the canal on the side nearest the river, in such a manner that their sills may be lower than the bottom of the canal itself. The waters that are occasionally suffered to precipitate themselves into the river from such apertures acquire great velocity. . . . . As this acceleration extends a considerable way from the opening of the grooves, substances are detached from the bottom. . . . . With several sluices of this kind, which are opened at proper times, and which are so distributed that at the spot where the action of one ceases, the action of another begins, the gravels which had entered the canals are forced to throw themselves again into the river in the least space of time possible.

The large irrigation works in these provinces suffer from the more subtle and more annoying, if not more dangerous of the two enemies, viz., silt. And no steps have been taken to exclude or get rid of it on the large canals in the plains, as none seem possible, owing to their great size and the large volumes of water they carry. But on the smaller water-courses in the Dehra Doon, measures have been carried out to intercept and remove the silt; and while the smallness of these water-courses allowed of this being done, it was of absolute necessity in their case that it *should* be done as will be seen further on. One thing that made it necessary was, that they supply water not only for irrigation but for domestic use.

The means by which water may be freed from its impurities are either, 1st, chemical; or 2nd, mechanical. With the former we have nothing just now to do; mechanical means are the only ones as yet employed in the Doon silt traps. All the methods of the second, or mechanical clearing of water, are one or the other of two processes—viz., subsidence and filtration. The first of these processes is of a negative character, consisting simply in letting the water remain for a considerable period in an undisturbed condition. It is well known that if a quantity of water having particles of any foreign matters of greater specific gravity than itself floating or diffused in it, be allowed to continue in a quiescent state for a sufficient length of time, these particles will subside to the bottom of the water, which is thus left comparitively clear and limpid. The process of filtration is effected by providing a bed of easily procurable materials, in which the water deposits the solid particles which it held in suspension, and finds its way to the lower bed in a comparatively clear state.

* Frisi on Rivers and Torrents.

Both these principles have been brought to bear from the earliest times. The Romans had their Limaria and Conceptacula. The former were open-air reservoirs or cisterns; the latter, reservoirs vaulted over, to shelter the water from the influence of the atmosphere. In the Limaria, the principle of subsidence was employed, and the stillness in the water requisite for it was obtained not merely by increased width and depth but also by change of direction. Thus (Fig. 1, Plate 16) the water flowed into the Limaria, at the point A, and its exit was at B, or at right angles to its original direction, which it regained by another turn. Filtration was performed in many ways, principally by taking advantage of the height to which the water was brought before it was made use of, by building one reservoir over another, and letting the water from the upper one flow into the lower.

Both these principles are also employed in the arrangements made for purifying the water intended for the supply of towns in England. I need not refer to those for filtering yet. Of the arrangements for the preliminary or settling process, I copy the following description of that employed by the Southwark Water Company, which bears most analogy to the method employed in the Doon.

"The system of cleansing adopted by the Southwark Water Company embraces settling reservoirs as well as filtering beds or reservoirs, and some peculiarities in the formation of the former deserve notice. The section (Fig. 2) will clearly show the construction. A, A, are the settling reservoirs, having an area of between four and five acres, and being 13 ft. 6 in. deep, and faced with gravel. The beds are formed with a slight inclination from the sides towards the middle, along which an inverted arch, *b*, is formed of brick-work in cement, 6 feet wide and 3 ft. 6 in. deep. This invert is an essential improvement, and with the inclined bed gives great facilities for cleansing by sweeping the deposits into the invert, and flushing it away with a current of water from an upper reservoir."

By this method the deposits are removed at once from the settling beds without these being kept out of use, which would be the case had the deposits to be removed by manual labour. But they are not thus got rid of, once for all. In fact, as the clear water after passing through the filtering reservoir has to be raised to the surface by means of a pump, it would appear that the deposits were only removed by the above means from the settling reservoir (which has to be kept in constant use) to some side pit or reservoir, from which they could be removed at leisure.

In Switzerland a construction is employed which combines the actions of settlement and filtering. A long rectangular reservoir is divided into a series of small square reservoirs by means of parallel cross walls. (See Fig. 3.) The water flows over the top and through an opening at the foot of each alternate one of these walls. Fig. 3 shows the mode of action at once, the water proceeding in the direction of the arrows. It is evident that this apparatus can be made to filter the water also, if required. But here too there are no means shown by which it may be rendered self-cleansing.

The mere impurities ordinarily carried by water bear but a small proportion to the volume of the water itself. The accumulated sediment would form no great mass during a long space of time, and the above contrivances are adapted for this state of things. But other arrangements were necessary on the Doon canals, where large sized gravel had to be got rid of, and where, during the floods in the rains, the water-courses ran with silt and water in almost equal quantities.

The water-courses in the Doon are taken off from the different hill torrents which flow down from the Himalayas, and which all flow over boulder and gravel beds. Owing to the great velocity of these mountain streams, due to the steep slope of their beds, they are always more or less charged with silt. Even during the winter months, when the water in three small canals appears to be flowing along in crystal clearness, a slight stoppage at any point will at once produce a deposit of a coarse blue sand. In the rains, when the hill-torrents come down in floods, the gravel of their beds begins to move; heavy masses of shale and gravel are brought down from the landslips which they cause, as they impinge on the sides of the hills which bound their course; and the streams become nothing but moving lines of silt and water, and thus enter the different water-courses of the country.

In the canals of the plains the silt is a sufficiently great evil. But the evils are chiefly that it entails great trouble and expense in removing it. It may prevent some improvements—as for instance, the introduction of the module—from being carried out, but it does not do any positive damage. It is, however, otherwise on the water-courses in the Doon. These water-courses are almost all of masonry. The slope of the country is so great that an earthen channel, which cannot in itself have a steep slope, would have to be provided with so large a number of falls that the expense would not be far below that of a masonry channel, to which a very rapid slope can be given, and which can thus carry water with a much less section, besides having a smaller number of falls. Besides this, every drop of water in the Doon is valuable, and a masonry channel prevents all loss from absorption. Thus the Doon water-courses may be described as long masonry conduits, having a section of from 5 × 2 feet to 10 × 4 feet, with a slope of bed of from 50 to 80 feet per mile, and still having numerous masonry falls, 5 and 6 feet in depth, on them. They also generally pass over numerous and long aqueducts. To these water-courses, therefore, the presence of silt causes immediate and absolute damage. The water rushes down these channels with tremendous velocity, and the gravels carried by it tend to injure all the masonry works over which they pass by the force of impact, while the silt acts even more injuriously, cutting into them with an action like that of emery powder. Even to a bed laid with large boulders great damage is caused; the mortar joints are washed out, the boulders lifted out of their places, and then rolled along the bed, to add to the mischief. But it is to brick-work that the greatest injury is done. In fact it requires but time to make all brick-work disappear entirely in the presence of such action. In some of the old canals there was a flooring of brick-on-edge over the arches of the aqueducts. On one of these aqueducts I have seen not only the foot in depth of the brick floor entirely cut through, but deep ruts formed in the arch itself. But it was on the falls, which were all formerly built after the ogee pattern and of brick, that the damage was greatest, as might be expected. Their surfaces were cut into deep striæ, and they were in constant need of repairs, which were difficult to execute.

It was therefore important, as a matter of mere canal conservancy, to keep the silt out. But it was also necessary for the sake of the people, as these water-courses not only supply water for irrigation, but also for domestic use. In the high, healthy, and best cultivated parts of the valley, the water in the wells is 180 and 200 feet from the surface of the ground. Wells are therefore practically useless. The people are dependent for their water supply entirely on the canals, and it is therefore necessary to have the water in them as pure as possible.

Thus, it was very soon after the construction of the water-courses themselves, that measures began to be taken to intercept and get rid of the silt. The relation between the courses of the canals and the natural feature of the country afforded an easy method of doing this. Taken off from various hill torrents, they rapidly rise above the bed of the parent stream, and for some distance from the head, and before they run on to the table lands they are meant to irrigate they have to run along the side of the hill or high bank at the foot of which the present stream runs. It is evident how the drop and hollow space between the canal and the river afford an opportunity for the construction of a reservoir such as we need.

(To be continued.)

THE OLDEST CHURCH BELL IN ENGLAND.

TO THE EDITOR OF THE CIVIL ENGINEER AND ARCHITECT'S JOURNAL.

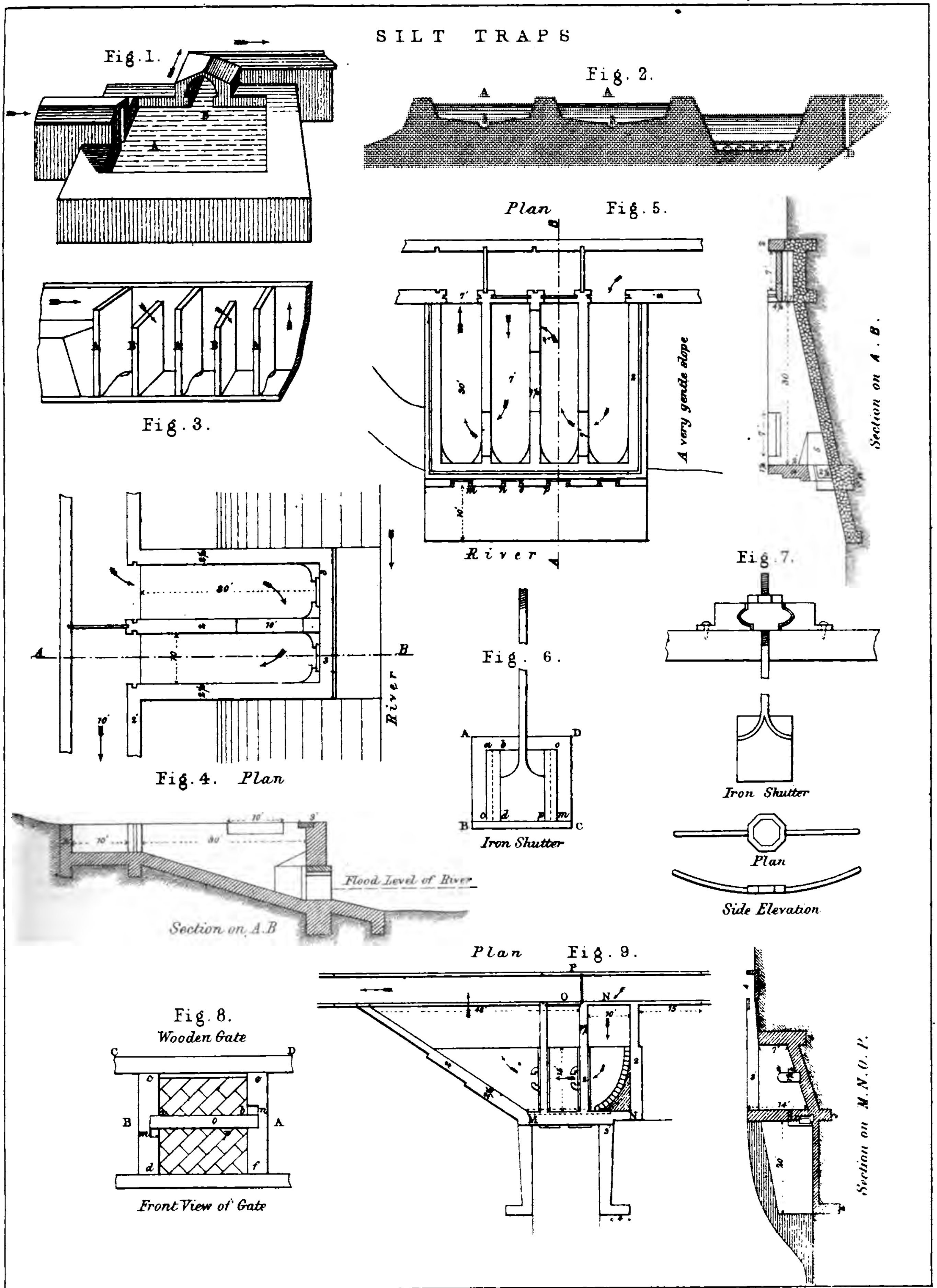
SIR,—I see Mr. Sperling has lately read a paper on Church Bells, at the Architectural Museum, which has been printed in your Journal, wherein he mentions a bell in Sussex, date 1319, as probably the oldest bell in England. Looking over some papers the other day, I came across a letter from an antiquarian friend of mine, sending me the inscription on a bell of his (then) church at Claughton, near Lancaster, as follows:—

ANNO . DOMI . M . CC . NONOG . VI . (1296.)

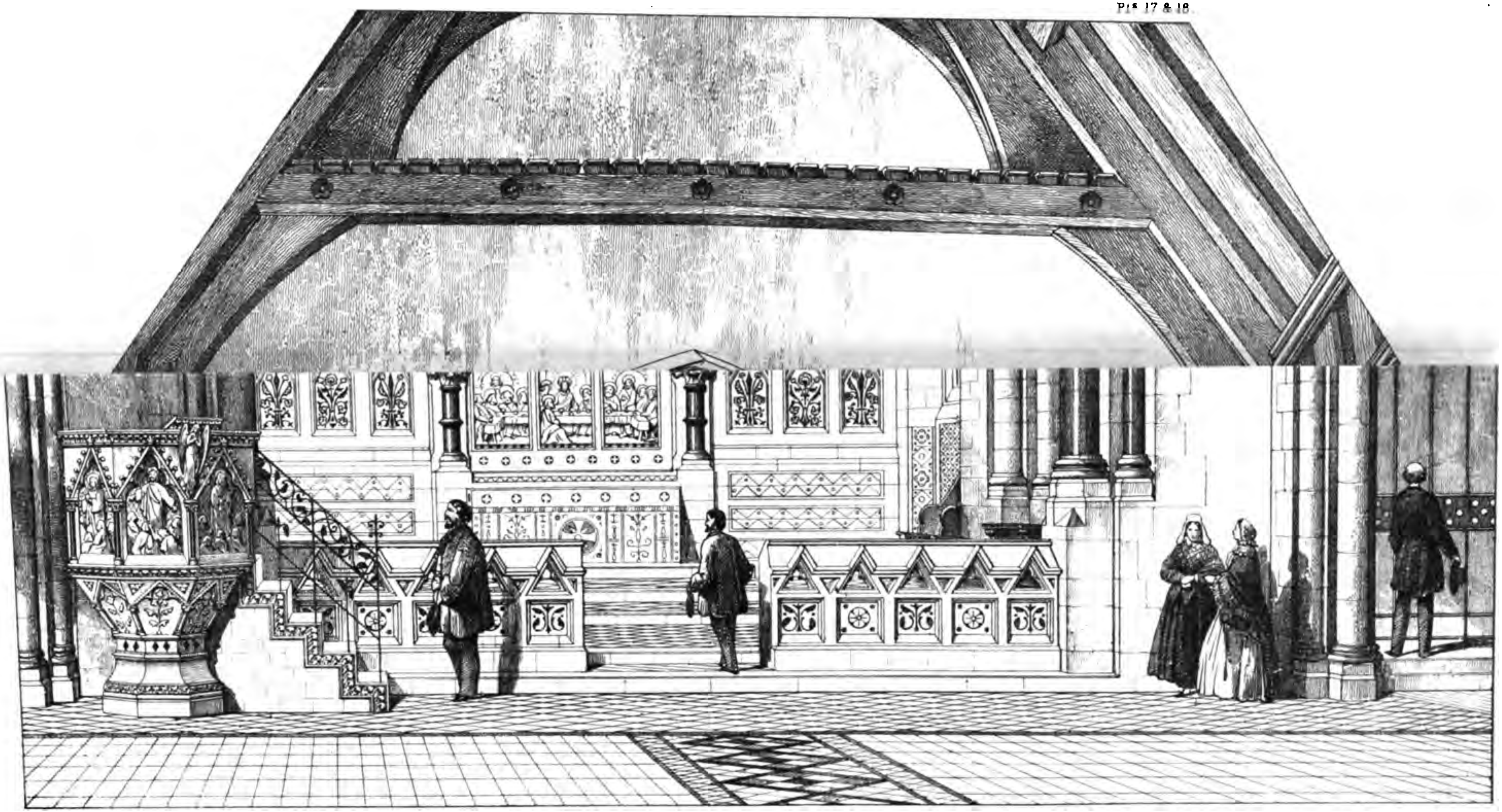
If this is correct, Claughton must possess the oldest bell yet known in England. I have often seen the bell in passing, as it is in the open bell-turret, and it has a very green and ancient look about it.—I am, &c.

E. G. PALEY.

Lancaster, May 9, 1865.


SILT TRAPS
Fig. 1.
Fig. 2.
Fig. 3.
Plan Fig. 5.
A very gentle slope
River
Section on A. B.
Fig. 4. Plan
River
Flood Level of River
Section on A.B
Fig. 6.
Iron Shutter
Fig. 7.
Iron Shutter
Plan
Side Elevation
Plan Fig. 9.
Section on M.N.O.P.
Fig. 8.
Wooden Gate
Front View of Gate

J R Jobbins



J R Jobbins

CHURCH OF THE RESURRECTION (ANGLICAN)

RUE DES DRAPIERS-BOULEVARD DE WATERLOO,

BRUSSELS.

INTERIOR OF NAVE LOOKING TOWARDS CHANCEL.

R. J. WITHERS, ARCHITECT, LONDON. 1864.

ARCHITECTURE AT THE ROYAL ACADEMY.

But a very few prefatory remarks will be needful before entering upon our general description of this year's architecture in the Academy. The situation and the space allotted to this branch of the sister arts, are the same to which we are now becoming reluctantly accustomed—viz. a half only of the small room at the top of the entrance stairs, and which in reality serves as a sort of ante-room merely to the exhibition itself, since the remainder of the wall-space is devoted to promiscuous drawings, with sundry chalk sketches, and miniatures; such a group as could not readily be classified among the general collection. Remonstrance against this unworthy treatment seems unavailing, and until the professional members of the academic body itself bestir themselves more energetically than they have done, there is little hope for amendment. It may be that their numbers and influence, being in the minority, have insufficient weight; still, if supported as they ought to be by their brethren and the public voice without, there can be little question that the pressure would be felt in the proper quarter, and matters placed upon their original and rightful footing.

Dispersed among the general list of pictures we note but few which indicate special attention to the delineation of architectural accessories, and most especially do we miss the hand of the late David Roberts, which maintained the connecting link, as it were, between the essentially pictorial and the matter-of-fact architectural developments of art, in which respect it will be long ere we shall see his like again. Stanfield, in some respects a congenial mind, never could be classed in the same category with Roberts, for though his power of handling the brush is in its way equally masterly, he has usually identified himself so much with subjects of another kind, as to make us forget that he, too, once was famed for the practice of artistic architecture. Mr. J. F. Lewis is one of the few painters of the highest stamp who bestows attention upon architectural details, which in his pictures are invariably correctly expressed, but this is merely in keeping with that exactitude in filling up the minutiæ of his works which distinguishes them from those of the majority of artists of the present day.

The "Richmond-hill Hotel," as being erected on Richmond-hill, from the designs of Mr. Giles (771), though less ambitious in its aspect than the now renovated Star and Garter, partakes of the same character, nor can we object to the free use of high-pitched roofs, which under such circumstances are such valuable auxiliaries in the composition and massing of an extensive building. The high roofs on the new Houses of Parliament, it will be remembered, were not contemplated in the original design, but probably, among the modifications which that building underwent in its progress, there was not one that has been attended with a happier result. In the design before us, verandahs and balconies form a conspicuous feature, though they are so well managed as not to interfere with the main constructive lines of the elevation, while in themselves constituting its leading architectural lines.

The next drawing is by Mr. Boulnois, forming, with (818), two out of the set submitted by him in competition for the new Grocers' Hall, in connection with which Mr. E. M. Barry here, and Mr. Blomfield in the Architectural Exhibition, are also partially represented. Mr. Boulnois' conception is, we are bound to say, wholly unequal to the subject. The frontage before us (772) too literally carrying out the idea of the matter-of-fact "block of offices," by which it is designated, giving a large unbroken surface of plain wall, divided into regularly storied heights, and with uniform ranges of similar two-light windows of the most ordinary character, and we have nearly all the ingredients of this composition. The interior of the Civic Hall itself is a better effect, but this likewise falls far short of the ordinary standard. Mr. T. Allom is an exhibitor of two good pictures, of works being carried out from his own designs, one (774) "The London and Lancashire Insurance Offices," at the corner of Leadenhall and Bishopsgate streets, and the other (777) "The Great Eastern Hotel," at Harwich. The latter is a large and noble-looking structure, in which we perceive some minor details similar to those in one of the most noteworthy of our modern west-end hotels.

To Mr. C. E. Davis was awarded, in February 1855, the first premium in a competition for Bath Forum House Bathing Establishment, &c., here shown in (776). The style is Italian, of the best class, though rather cramped in its proportions. The plan indicates three sides of a quadrangle. Overstone Hall, Northamptonshire (778) claims attention not merely from the size of the building, but from its peculiar architecture, which, though we presume entirely new, partakes largely of the objectionable features which marked one phase of the Jacobean transition period; especially in its block-banded columns, &c. Except for the eccentricity of this treatment, it does not call for a word of remark, and we should have been glad if Mr. Teulon had spared such absurd revivals in the present day. A little sketch of "Schools now being erected at Littlebury, Essex," by Mr. E. Barr (779), has the advantage of good outlines and a well-devised composition. There is no plan attached. In the adjoining frame, Mr. R. M. Phipson includes views of three churches which he is restoring in the eastern counties, apparently in a very common-place way.

Bramling House, near Wingham, Kent (784), is one of the most sensible-looking modern buildings in the exhibition. There is no needless pretension, yet everything has been unquestionably well studied with a view to effect as well as comfort, and at a reasonable outlay. In this it ranks amongst the best works of the architects, Messrs. Banks and Barry. These gentlemen also exhibit (793) the new "Westminster Chambers, Victoria-street," a handsome and uniform design, now approaching completion, and which is one of the many gigantic and enterprising schemes which have sprung up on the Limited Liability Company system. Still more extensive are the new buildings of the "Piazza Statuto, Turin" (794), now in course of erection on the same principle by Messrs. Banks and Barry, and bearing no slight similarity in point of design, though perhaps less vigorous. This may possibly be in part attributable to the architects having had to work upon a design already prepared by a local architect, but to what extent this proved an obstacle there are before us no means of determining. The interior of Worcester College Chapel, Oxford, is here shown (785) by Mr. Burges, in its remodelled form; the alteration in effect being mainly effected by the polychrome decoration with which the whole surface is studded, in very questionable taste, as we venture to suggest. The plain character of the building, which is in the Roman style, remains as before. Mr. Ferrey contributes this year (787) a perspective of a mansion which he is altering for Lord Dufferin, at Clandeboye, of which sundry marginal sketches and a plan convey some idea in its present state. That the alterations may be characterised as safe is not perhaps saying much, but there is really so little to challenge criticism, that one is at a loss for a more appropriate term. The chief metamorphosis consists in the change of style, from most insipid Classic to correct but feeble Gothic. In contrast with this we may note Mr. J. P. Seddon's clever and vigorous restoration of Great Yarmouth Church, of which he gives (788) a north-east view. This church is one of the most interesting in that part of England, while, from its large size and other circumstances, the idea of retrieving it from the lamentable state of decay and neglect into which it had fallen seemed a hopeless one. Nevertheless much has been accomplished, and with so much success as to encourage the ultimate prospect of its entire restoration.

Mr. Gilbert Scott is not an exhibitor this season; but one of his most recent ecclesiastical works—the restorations at Hereford Cathedral—is represented (789) by a large interior view of the choir, prepared by Mr. J. Drayton Wyatt. This view is taken from almost the extreme east end, and thus comprises the new organ erected on the south side, the elaborate choir-screen in metal, by Skidmore, which formed so prominent an object in the last International Exhibition, the beautiful ancient oak stalls, as restored, and the rich encaustic pavement with which the whole area is covered. The "Randolph Hotel," Oxford (791) is by Mr. Wilkinson, of that city, and, like most of that gentleman's works, is in the Gothic style. Unfortunately, from its position, being placed so high up, it is impossible to examine closely the details of the design, which however are in effect good. The structure is immediately opposite to the late Professor Cockerell's well-known Taylor and Randolph Buildings, to which therefore it offers in more than one respect a decided contrast. There is nothing prepossessing in the appearance of Messrs. Searle and Co's "Royal Albert Orphan Asylum," at Bagshot (792), which, though large, presents a very meagre Italian façade, and little more. (795) and (806) are designs for west-end domestic architecture, by Messrs. G. E. Street and E. M. Barry respectively, and both stated in the catalogue to have been prepared for the Marquis of Westminster. The one, it will be naturally inferred, is as decidedly Gothic in character as the other is Classic. Mr. Street adopts a very picturesque outline in his "houses," which have high-pitched slate roofs, with dormers, &c. The walling is chiefly of red brick with stone dressings. Some of the windows are coupled, but many of them are treated as bays, after the Venetian type; while at the principal angle one is corbelled out as a circular oriel, with bold effect. There is, too, a degree of novelty to be observed in the design of the entrance doorways, which are also treated on the corbel system. Mr. Barry's design quite identifies itself with its author, and displays a reproduction of many features which he has of late successfully employed in his larger works of this class. One of the chief of these, is the use of terra-cotta to a large extent, both in surface work, and for the purposes of ornamentation.

St. Mary's Church, Ide-hill, Kent (796), is an unpretending edifice, so far as size and ornament are concerned, but Mr. Charles H. Cooke has contrived, by a judicious grouping of parts, to produce a very satisfactory effect. Five drawings in one frame (799) illustrate Mr. Digby Wyatt's re-erection of the "Ham," Glamorganshire, for J. Nicholl, Esq. This is in the florid Elizabethan style, and would appear to be carried out in an elaborate manner. Such a building will be, we suspect, quite *per se* in the Principality. Mr. Wyatt also exhibits (821) "Addenbrooke's Hospital, Cambridge," and (822) an "Original study of a design for the proposed Shakespeare monument at Stratford-upon-Avon." The former is now almost complete, and appears in reality, as in the drawing before us, to lack a more decided cornice, and some upper members, to break the hardness of the straight sky-line. The principal front generally is somewhat tame in appearance, notwithstanding the continuous arcading (rather slender) which is its distinguishing feature. The latter is simply a modification of a Roman triumphal arch, decked out with a kind of Elizabethan garnishing, the appropriateness of which it is difficult to conceive.

Mr. E. M. Barry's "Design for the Grocers' Hall," appears in two drawings (800, and 816). The former showing the interior of the principal room, or Livery Hall, and the latter the general external view. The hall is an oblong room, with a coved ceiling, and lunettes; the whole lighted from above by three domes. Along the walls are detached Corinthian columns, at intervals, set against pilasters, and having the main cornice or entablature broken round them. As a whole, though the effect is good, there is nothing particularly striking. This also applies to the exterior, which is architecturally correct, so far as it goes, but has no sympathy with the ordinary character of city halls, ancient or modern, which we hold to be a drawback to this design. The details are throughout of the Corinthian order, columns being freely used outside as well as within. The contrast between this design and that in (772) is worthy of remark.

The "Scottish National Memorial" to the late Prince Consort, is represented by two drawings out of those sent in competition. In the first of these (801) Mr. W. A. Carter has aimed to engraft some of the peculiarities of northern architecture upon the more usual adjuncts of such memorials. Thus, the upper part consists of an open "crown," such as distinguishes the summit of one of the most noted churches in Edinburgh, but here it does not sit comfortably; indeed the whole outline, from the base upward, is anything but pleasing, being apparently overloaded, especially considering the slender supports on the lower story. The second design exhibited, that by Messrs. Slater and Carpenter (810), does not err so much in this particular, but is very rigid in its proportions, and not happy in its details. The governing idea is evidently borrowed from the memorial now being erected by Mr. Scott in Hyde-park. Like that it consists of a pedestal with shrined figure above, surmounted by a lofty pyramidal canopy, on the "Eleanor-cross" model. We look in vain for the merits which recommended to the favour of the hanging committee the exterior of Mr. F. Marrable's proposed new church at Deptford (802). Surely, among the innumerable rejected drawings in this church-building and church-exhibiting age, it would have been easy to have selected many more worthy to occupy the space. In the interior, however (811), there is a degree of novelty which is capable of being turned to good account. This is most noticeable in the roof or ceiling. In the "National Provincial Bank of England," now in course of completion in Threadneedle-street, Mr. Gibson has had the opportunity of constructing an edifice of gigantic proportions, and one which promises to keep pace with the manifest improvements in the aspect of city buildings generally. The exterior, shown in (814), is of one lofty story only, of the Corinthian order; the wall space upon the intercolumniations having in the lower part a window, and in the upper part a large sculptured panel. Internally the principal feature of the banking room (805) is a succession of noble columns of red granite, coupled along the walls, but there is also much sculpture, and the ceilings are richly ornamented.

It may be remembered that the Soane Medallion of the Institute was last year awarded to Mr. T. H. Watson, and that gentleman accordingly exhibits (807) his successful design, which is for an "Asylum." The style is Gothic, and in its manner of treatment displays much originality, but here we must again take some exception to the general impress of the design, which seems quite foreign to its purpose. Especially should we single out as questionable, both as regards utility and taste, the church-like steeple attached, though in some respects a clever composition, which may be described as on the wagon principle, but partaking of that of the ridge-and-furrow also; the lines running transversely to the building, between the moulded principal ribs into which the construction abuts, and which are themselves in one large pointed arch springing from corbel shafts attached to the side walls.

The success of the Metropolitan Main Drainage scheme has at length achieved a worthy reputation, and much of this success is due to the energy and skill of the engineer, Mr. Bazalgette. The two large drawings here exhibited by him (808, 809) give a very fair idea of part of the exterior, viz., the "Southern outfall Pumping Station," in which, as well as in the practical construction generally, the brickwork is beyond all praise. To relieve the monotony of large plain surfaces of one colour, lighter and darker red bricks are employed, as well as an additional colour for special patterns. The high roofs, with their ornamental metal work, are of great assistance to the effect, and the lofty detached shaft, square on plan, is another decidedly advantageous feature. Reference was made, in noticing the Architectural Exhibition, to Mr. E. B. Lamb's clever design for the Ipswich Town-hall. If anything were wanted as a foil in support of this opinion, it would be difficult to find a more certain one than Mr. Ellis's competitive design for the same building, which is numbered in the Academy calalogue (804). A more feeble effort is seldom to be witnessed.

No. 812 is the design for the restoration and enlargement of the fine old church of St. Paul, Bedford, as originally submitted by Mr. R. Palgrave, the architect selected for the work, and which is now, we believe, about to be commenced. The prevailing character is Perpendicular, and to this style Mr. Palgrave has very properly adhered in the contemplated additions.

A large view of the choir, internally, of York Minster (817) by Mr. W. J. Boddy, claims attention, from the conscientious fidelity with which every part is delineated, while it forms a very complete and handsome picture.

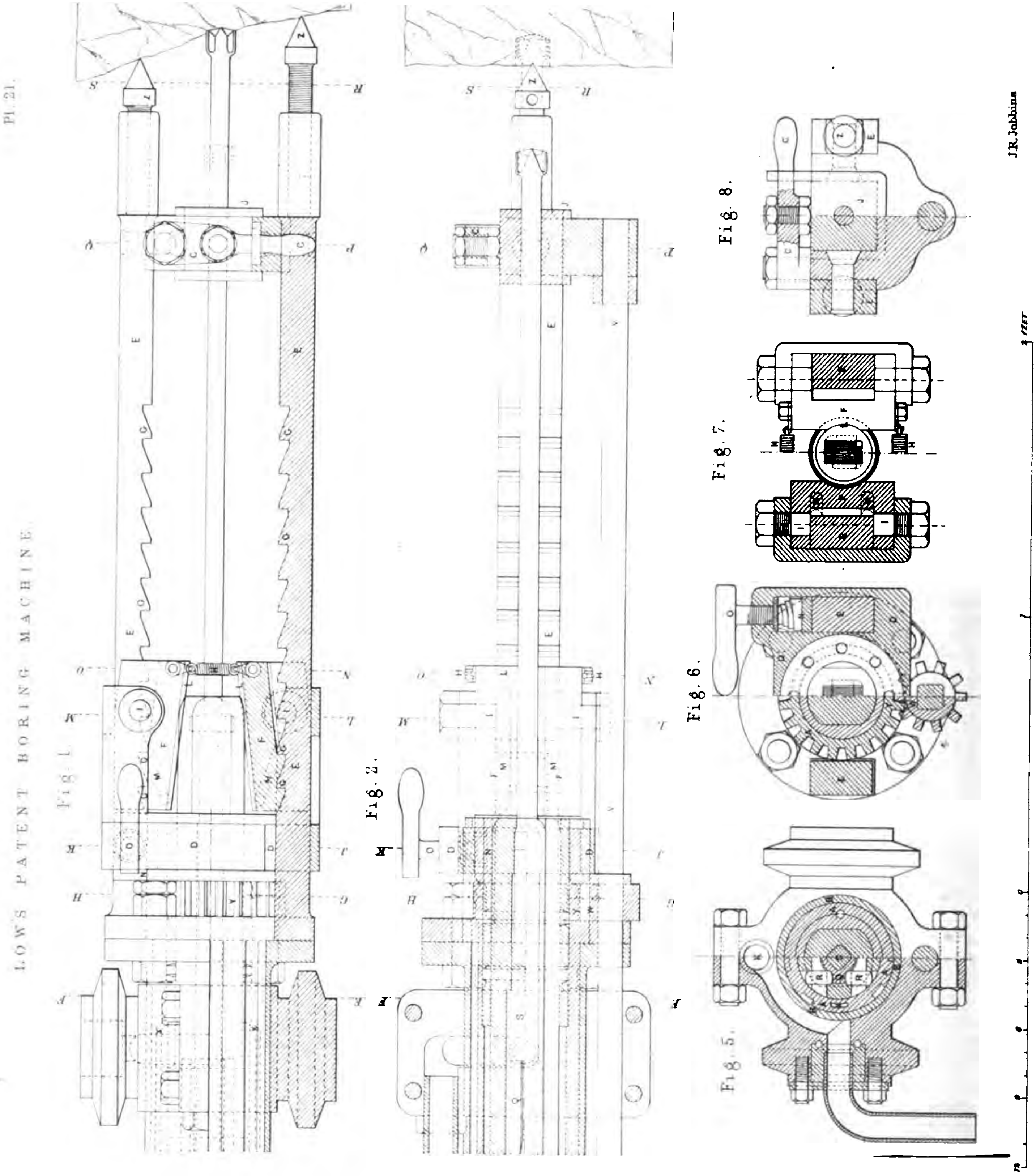
Sir Morton Peto's new mansion in Kensington Palace-gardens, is partially shown in the view (823) of the garden front, exhibited by the architect, Mr. Murray. The style is Italian, and it may be described as rather dignified in its proportions than elaborated in its detail; nevertheless it will present, doubtless, a handsome appearance if carried out in its entirety. "Ospringe Church, Kent," (825) shows a new tower and some other restorations now in progress from the designs of Mr. Blackburne, which are of a satisfactory kind. It is intended to cover the tower with a pack-saddle roof. "Castle Carr," a mansion at Halifax, now in course of completion from the designs of Messrs. A. Smith and T. Risley, is shown in two drawings, (813, 833) to be in the castellated style, and to have for its most prominent feature a round tower.

There are, comparatively, few illustrations of existing old buildings. The "Sainte Chapelle, at Paris," appears (831) in its modernised guise, a mass of polychrome decoration, "regal in splendour," yet, after all, but a questionable success if tried by the canons of true art. The time devoted by Mr. Baylis in the manipulation of so large a picture must have been enormous. Among ruins here shadowed forth, we find those of Newark Abbey, Send, Surrey, by Mr. H. P. Ashby; the Temple of Vesta at Rome, by J. M'Whirter; and the Arch of Titus, also at Rome, by Mr. Spiers. We observe also a clever drawing of one of the porches of Lausanne Cathedral (827), by Mr. E. George; the interior of St. Michael's Church, Ghent, by Mr. V. P. Sells; and a painstaking view of the Hall of Ambassadors at Seville (828), by a lady contributor, Miss G. Wilkinson.

The exhibition will be closed at the end of the present month.

[illegible] repeated misfortune to see sections of our mining populations, by foolish and disastrous "strikes," paralysing the healthy energy of entire districts. Surely, then, it is high time the mechanical engineer should be invited to step boldly in

powder may displace the rock to the entire depth of the holes. Of the above 80 holes four are bored of 4 inches diameter, in centre of gallery, and the others, $1\frac{1}{2}$ inch diameter, are distributed equally all over. These four large holes serve to weaken the



edifice of gigantic proportions, and one which promises to keep pace with the manifest improvements in the aspect of city buildings generally. The exterior, shown in (814), is of one lofty story by a lady contributor, Miss G. Wilkinson.

The exhibition will be closed at the end of the present month.

LOW'S PATENT BORING MACHINES, &c.

By John Downie.

(*With an Engraving.*)

The subject of the following paper is "Low's Machinery, as applied to Working in Rock or Minerals, in Tunnelling, Driving Adits, Perpendicular and Inclined Shafts for Mines; Working against Face and Surface of Quarries; Open Rock Cuttings for Railways or other such purposes; to Coal Cutting and to Mining operations generally, in lieu of the very slow laborious, and unhealthy method of executing the above kind of work by hand; with a few remarks on some of the other most recent appliances for Mining purposes."

In most countries, for many centuries past, the art of mining has been practised; and long before the days of steam-driven machinery, and even before the invention of gunpowder—the modern miners' powerful assistant—the British Isles were famed for, and gave forth their mineral wealth to enrich their then powerful possessors.

From this extended field of inquiry I shall offer a few ideas more for future guidance than to afford information for present wants. The application of machinery, in one form or another, has now become universal in almost every branch of industry; but only within, I may say, the last ten or twelve years—since the alteration of the Patent Laws in 1852—and more especially the last four or five years, has there been any decisively marked advances made in the application of mechanical power as a substitute for manual labour in the extraction of the mineral wealth which may be truly said to be the very basis of our nation's greatness. This is the more remarkable when it is considered how much engineering has already done in all labour-saving and work-expediting processes, and when it is an admitted and well-established fact that in every case of the removal of hard rock or "winning" of minerals—such as iron and copper ores, for instance—one of the greatest items of cost generally is the wages paid for excavating by "holeing" or "jumping," or otherwise perforating the rock or mineral to receive the blasting charges.

That these things have been experienced and deplored by almost every mining engineer or employer who has had to do with such operations, argues that the very great difficulties standing in the way of cheaply and successfully applying mechanical power to these operations, have hitherto deterred proprietors of mines from stepping out of the beaten path, and employing the great engineering mind of this and other countries to overcome these difficulties, and that now the time has arrived for giving the subject that attention that its importance deserves. The requirements of our extended commerce in minerals, which may be taken for the present year in round numbers of one hundred million tons of coals, raised in these islands alone, irrespective of all other minerals, imperatively demands it; and when we must dig deeper into the bowels of the earth for the vast untouched riches underlying our present exhausted mineral beds, and which, as Prof. H. D. Rogers has shown in his admirable writings, may be expected to be more productive than any present workings, it becomes absolutely necessary that the aid of machinery should then be obtained, as the human frame would not be able to stand the heavy work required in the high temperature of, say 100° and upwards in the lower coal measures, induced by the known average increase of 1° of Farenheit to every 300 feet from the surface. This, coupled with the increased difficulty attending the ventilation of such mines, are conditions met at once by the application of compressed air-driven machinery, which, after doing the work of excavation, wastes not its residual products, but spends them in giving a most effective ventilation, by thoroughly diluting the dangerous gases composing the "fire damp," or explosive compound of native coal-gas, by the exhaust being discharged at the high velocity due to its density, thus doing what is technically called "dashing" by the miners, to secure their safety, and at the same time giving them a healthy atmosphere with the very low temperature due to the expansion of the air on being released, and that at the points most required, viz., the face of the workings. And were such powerful reasons as these not of sufficient weight for the speedy introduction of machinery in mining, we have of late had the frequently repeated misfortune to see sections of our mining populations, by foolish and disastrous "strikes," paralysing the healthy energy of entire districts. Surely, then, it is high time the mechanical engineer should be invited to step boldly in with his appliances, to do the arduous drudgery of mining; and thus, by raising the miner to be the director of that energy the engineer has put in his hands for the general benefit of all, effect —by this to him more inviting form of labour—a reformation that nothing else can do for the elevation of that class of our fellow-men.

The difficulties surrounding the problem being admittedly great, the greater credit will be due to those who surmount them; and in order that this subject may be opened up and ventilated, I will endeavour to submit some record of progress in this department of engineering in a reliable form. I shall therefore give a rapid survey of some of the mechanical appliances that have recently been brought to bear on these important operations; and, more particularly, to describe some excedingly ingenous and effective machinery for this purpose at present employed in Ireland, in the execution of the tunnel at Roundwood, in the Wicklow mountains, in the line of water-works at present being constructed for the Corporation of the City of Dublin, and with which I have had some little to do. It is the invention of Mr. George Low, engineer, Millgate Iron Works, Newark-on-Trent; and to whom I am indebted for much valuable information on the subject under consideration,

I propose, then, to divide it into two principal heads, viz., "Tunnelling" and "Coal-getting;" incidentally touching on the other applications in illustration of the drawing, and speak on all of them in a general way. In doing so I shall simply make a selection of only a few machines for sake of comparison, as it would take up too much time to go over seriatim the eighty-three or more British patented appliances for mining, exclusive of all foreign inventions for similar purposes, that have been brought out since 1792, till the end of 1864. The selections therefore shall be discursive, and only the salient features of each rapidly described, premising always that this class of machinery, having been comparatively recently introduced into general use, it may therefore be considered as still in its infancy, and that very much has yet to be learnt about it ere it can be perfected.

1.—*Tunnelling.*

The first of the tunnelling machines I will notice is the celebrated one at present engaged in boring the Mont Cenis Tunnel, invented by M. Sommelier, and manufactured by the Société John Cockerell, at Seraing.

It has eight borers or cylinders, with their appendages, each weighing about 6 cwt., mounted in a carriage frame weighing about 15 tons, which also carries the air receiver and water tank, or reservoir, for injecting water into the holes to clear away the *débris* as the boring proceeds, the pressure for this purpose being given by a communication between the two receivers. This apparatus, then, is designed to drive an advance gallery 9 feet square, which is opened out by hand labour to the intended size of tunnel, about 26×24½ feet. Each borer consists of a traversing boring cylinder, within which works a piston carrying the boring tool, which slides along a double frame with worm rack, on the inside edges of which work worms actuated by an auxiliary steam engine of 4 inches stroke; these are bolted on each of the double frames of each borer, and they also serve to work the slide valve of the boring cylinder and rotate the tool. The length of stroke of the jumper or drill varies from 2 to 7½ inches, and the average rate of working varies from 200 to 250 blows per minute, the boring tool turning completely round for every 16 strokes. The piston of borer (on which the effective pressure in striking is about 200 lb.) is formed with a large area and a small one, against which there is a constant pressure. The large area is acted upon by an intermittent admission of air, which overcomes the pressure against the smaller one, and so causes it to strike, when the air escapes into the atmosphere. The constant pressure against the small area causes the piston to return after each blow. The cylinder is advanced at each blow by the worm aforesaid, and provision is also made by which it will advance according to the rate at which the tool is cutting, whether the rock be hard or soft.

In consequence of the great length of these boring cylinder frames, viz., 13 feet, all the holes are bored horizontally, or nearly so, which necessitates a great number of holes to be bored (viz., 80), 3 feet deep in a space of 9 feet square, in order that the powder may displace the rock to the entire depth of the holes. Of the above 80 holes four are bored of 4 inches diameter, in centre of gallery, and the others, 1½ inch diameter, are distributed equally all over. These four large holes serve to weaken the rock, so that the holes in their immediate neighbourhood (which are first blasted) form a chasm, which enables the other holes (which are fired in succession nearest to the edge of such cavity till the sides of gallery are reached) to displace the débris easily.

At the Bardonèche or Italian end of tunnel, the air working the machine is compressed to about five atmospheres by the alternate descent of water down a pipe 85 feet high, which being admitted into a cylindrical vessel 2 feet diameter by 14 feet high, thus drives the air before it into a receiver, when the water is allowed to escape by a valve at bottom of pipe. The valves for letting a portion of water down to act as a piston, at the rate of about 2½ strokes per minute, and for letting the same escape after forcing the air into the receiver, are worked by a donkey engine. This compresing apparatus is capable of supplying about 20 cubic feet of air per minute at the pressure already named.

The air actuating the machine at the Modane, or French end of the tunnel, is compressed by compressers worked by water wheels of 6 metres diameter. The cost of each borer is, I believe, about £80 sterling; but this can give not the faintest idea of the cost of the immense plant (something between £80,000 and £100,000) used on that gigantic undertaking, in the execution of which some 2500 men are at present constantly employed, and which will yet take years to complete.

It may be well at this stage to add that credit is claimed for Mr. Thomas Bartlett, C.E., a gentleman connected with the well-known house of Brassey & Co., as being the first inventor of a mechanical jumper for rock, and which has become the starting point of whatever has been since achieved at Mont Cenis.

Schwartzkopf and Phillipson's—These machines are in use in the Swedish mines, and consist of a column carrying a jib, which is raised or lowered by a pinion working in a rack. The boring cylinder, with piston, is the same as in an ordinary steam-engine; the valve is conical and circular, and is turned by a spiral groove in cross-head of piston-rod. This cylinder is traversed along a single frame by means of a screw by an attendant (according as the boring proceeds), exactly in the same manner and design as an ordinary slide-rest of a lathe. The rest or frame, with cylinder, is carried by the jib; the boring tool is loosely held in the end of cylinder frame, and is turned by a rachet, the pawl of which receives the same motion as the circular valve, being worked off the valve spindle; the boring tool, unlike the Mont Cenis one, receives its blows from the end of piston-rod; and, to allow the debris to get clear out of the hole (in consequence of the tool not reciprocating), the tool has to be made of a spiral form, like a wood auger, to allow the debris to wind out; when set to work, the column is jammed fast by clamps betwixt the top and bottom of adit in the desired position.

The piston makes from 1200 to 1400 strokes per minute, and bores Norwegian granite at the rate of 1¼ inch to 1½ inch per minute.

Captain Penrice's—This tunnelling machine is a powerful and colossal one, and consists of a large face-plate (the diameter of the tunnel to be bored), with several rows of some hundreds of steel chisels across its diameter. This face-plate is mounted on a massive axle, working in bearings, at the end of which is the piston, working in a central cylinder, and has a large and small area, the same as in the Mont Cenis cylinder. The valve is an ordinary slide one, worked from a pair of donkey engines, which latter also propels the carriage containing the boring machinery, boiler, &c., by means of worm wheels, and worm geared into the rollers, carrying the whole machine. The face plate also gets its rotary motion by a worm wheel affixed on the axle, into which a worm gears, and is worked by one of the above donkey engines.

The operation may thus be described: the face-plate, with its numerous chisels, receives its reciprocation from the above central cylinder. After each blow it is turned slightly round, at the rate of 2½ revolutions per minute. The entire face or heading of tunnel surface is thus struck or triturated into small fragments or particles, which, upon falling down, are caught by an endless creeper, worked from a third donkey engine, which conveys the debris underneath its entire length, and delivers it at back of machine.

It may be here mentioned that this machine would only do for soft stone; and the immense number of chisels take considerable time to take out and replace them when they require sharpening. I believe this machine was tried in the Malvern tunnel, on the Worcester and Hereford Railway, and also in the red sandstone in the neighbourhood of Newcastle-upon-Tyne, and was exhibited at work before the members of the British Association.

Crease's Machine, of which there are several modifications, in its principal features is the same as that of Schwartzkopf and Philippson, the first being made to strike the tool; but latterly they are constructed to reciprocate with the piston; and a recent patent shows that the valve is a steam moved one, similar to Joy's or Colburn's valves. As the machine is so very similar to Schwartzkopf and Philippson's it will be unnecessary to describe it here. I believe one of them has been much improved by Greene, and is at work at the Clogan and Vigra gold mine.

Gay's (of Paris) Machine consists of a cylinder the diameter of the tunnel, or say 6 ft. 8 in. diameter by 2 ft. 4 in. deep, and say 1½ inch thick; and round the front edge are fixed steel chisels at intervals for soft stone, prisms of flint agate, &c. for ordinary rock, and prisms of diamond for very hard rock. It is carried on an axle working in suitable bearings, and this axle carries a central boring tool. The cylinder and central tool receives a rotary motion from a belt or wire-rope, worked from a steam or air-engine, working in a pulley on a cross shaft, which gears into the axle by a pair of bevil-wheels—thus making a circular trench and a central hole. A rope is attached to the end of axle, and passed over a pulley, at the end of which is a heavy weight for the purpose of keeping the cylinder and central tool steadily pressed against the rock while boring. Upon the necessary depth being attained the machine is withdrawn, and another is placed to widen the bottom of the central hole in order to make a powder chamber, which upon being blasted will displace the whole mass out to the depth of the circular trench. I understand this machine works very well and rapidly, but I am not aware where it is working. A machine of a similar kind was made in Boston or New York, America, in the year 1852, and worked, it is said, at the Hoosic Tunnel; it was designed for cutting a circle 24 feet diameter.

Vallauri and Buquet's Machine, made by Cail & Co. of Paris, the celebrated engineers, is composed of two carriages, the lower one being mounted on six wheels and the other is placed on top of lower carriage, along which it slides in two V grooves after the manner of the table of a planing-machine. At the end of the top carriage is a cross axle carrying four quarters of a circle, one on each side and the other two intermediate. The diameter of the quarter circles when revolving is nearly the height of the tunnel: on the periphery of each quarter-circle are steel points, placed at intervals, and so set spirally that each cuts its own portion of a groove in the rock. These quarter circles are caused to revolve vertically by a wire-rope worked from a portable engine outside the tunnel, after this manner. The portable engine works a cross shaft by two belts, and the wire-rope is placed once round a pulley on the said cross shaft and round the driving-pulley on the machine, and the other end passes round an anchor tender, which latter runs on rails outside the tunnel, keeping the rope at one uniform tightness, and as the machine advances the tender will also advance. The driving-pulley gears into a counter shaft, from which a train drives the axle carrying the above quarter-circles, thus cutting four vertical trenches from top of tunnel nearly to the bottom, the top carriage being advanced by a screw and hand-wheel actuated by an attendant. The lower carriage is mounted on eccentric wheels, and is occasionally turned down to the lowest point of eccentric, so that the circle may cut the trenches quite to the bottom of tunnel.

I believe this machine has been at work in the Pyrenees and Carrara, and one claim the inventors put forward is, that this method does not require the employment of powder; another is, that the high speed of driving-rope keeps up an excellent ventilation, and by working two machines alternately the system allows of the removal of the debris without interrupting the progress of the work.

De la Haye's Machine consists of two frames, adjustable as to height or length, which are secured between the top and bottom of shaft or adit. These frames carry a horizontal carriage for tool, which is caused to reciprocate and cut a trench after the manner of a plane; the raising or lowering of such, according as it executes the work, is done by an attendant. This machine is also adapted for cutting in a vertical direction, but I am not aware as to what power is employed to work such carriage.

Freeby's Machine.—The principal features of this consist in a number of spindles carrying the tools, say eight or more, in a cast-iron frame, which slides along a lower frame mounted on wheels, and so arranged that it can be set at an angle, slightly vertical or horizontal, across each and midway of the spindles, one of which is driven by a belt which drives all the others by intermediate cog gearing. On each of the cross shafts is a revolving cam, which strikes a 7-toothed circular cam on each of the longitudinal or tool spindles, which partly turns and presses them against a spiral spring, and so soon as the revolving cam slips clear, the spiral springs cause the tools to strike.

SAX's Machine resembles that of Schwartzkopf and Philippson, and works succesfully in a tunnel near Aix-la-Chapelle; but in the absence of information or details I am unable to describe it.

MUNRO and SCOTT's consists of circular cutters, which reciprocate a part of a circle, and are worked from a circular steam chamber, in which a piston also works partly in a circle. The steam chamber with circular cutters is traversed up and down in a frame, and from side to side, cutting a trench around the tunnel.

WESTMACOTT's Machine, working at Mr. Beaumont's mines in Allenheads, was introduced by Mr. Sopwith. It is worked by water pressure, and strikes the tool same as Schwartzkopf and Philippson's. It is reported to work satisfactorily, but some trouble is experienced in keeping the holes clear of debris.

2.—*Coal Cutting.*

Machines of this class have been proposed for sawing or trenching by rotating cutters, by cutters fixed on an endless chain, by drilling, and by jumpers, paring by traversing tools, and "hewing" or "kirving" by means of a traversing pick fixed in a vibrating lever, and actuated by engine power or otherwise. Of these I shall only notice, in a very brief way, a few of the most recent appliances.

FRITH and DONNISTHORPE's Machine was first introduced at the West Ardsley Colliery, near Leeds. It has been ably described in an article in 'Good Words' for April 1864, written by Professor Henry D. Rogers, LL.D., F.R.S., of Glasgow University, and in which many interesting and instructive details, well worth the perusal, are given by that learned gentleman and keen observer.

There are two machines of this class at work, I believe, at Hetton Main Colliery, and one at the Marchioness of Londonderry's Colliery, both near Durham. It is worked by compressed air of, say 50 lb. or so per square inch, acting on a reciprocating piston at the rate of about 90 to 100 blows per minute, and giving motion to a heavy pick, which cuts a horizontal groove, on the "long wall" system, of from 2 to 4 inches wide—instead of 10 or 12 inches by the usual "hand kirving"—by about 3 feet deep and about 100 yards in length of "benk," in about eight working hours. The attendant with one hand manages the valve which gives the stroke to the pick, and with the other moves the machine along. The return stroke is given by the engine automatically.

I have no reliable data as to the comparative cost of coal-getting by this machine; but doubt not, as the extension of this system of mining proceeds, the working charges will be much reduced, as one set of air-compressers and their other plant may be sufficient to supply many machines, at a much reduced outlay for attendant labour, &c.

RIDLEY's Machine is very similar in its action to the one just explained, and the general description of its power gives as a day's work (of three shifts of 8 hours each, or 24 hours for one machine) the "kirving" or under-cutting 200 to 300 yards of long-wall face to a depth of 3 feet. This rate includes all necessary stoppages, and changing the machine from one "benk" to another.

The average speed of pick is from 65 to 80 blows per minute, and the rate of advance after each blow about one inch, the depth of cut being about 2 feet in the first, and 12 to 14 inches in the second cutting. This gives an average speed of traverse of nearly 1 foot lineal per minute for this machine, when all is in first-class order. The length of this machine is 40 inches, and it is specially adapted to seams of 2 feet thick and upwards. Its weight is about half-a-ton, and cost about £70, with one penny per ton royalty.

Two of these machines are said to be at work at the Earl of Durham's New Bottle Colliery; two at the Broomhill Colliery, Acklington, Northumberland; one at Suydle Colliery, Pontefract, Northumberland; and several others in Yorkshire, Lancashire, and Scotland.

JONES' Machine has a trunk cylinder (though this is not an essential part of the design) and a very simple and ingenious method of turning the pick to any angle from horizontal to vertical, and to either side, by means of a worm working into a wheel cast or fitted on the rocking shaft bearing, and thereby carrying round the trunk and whole apparatus in the desired direction. The cylinder also is made to move longitudinally on the carriage, so as to adjust the blow of the pick to any point that may be necessary. The valve is worked by a piston in its back stroke striking against a rod, which passes through the back end of the cylinder, and actuates a lever connected with valve-spindle, having an elastic pad of india-rubber introduced in lever, to take away part of the concussion. The forward motion is by a hand-wheel and gearing like the others. These machines are at work at the High Royd, the Oaks, and the Wharncliffe Silkstone Collieries, in the neighbourhood of Barnsley. Their performance is said to be from 10 to 15 yards per hour, 3 feet under, and cost about £70 each, exclusive of royalty.

CARRET's Machine.—This is actuated by hydraulic pressure on a piston having a sort of paring tool attached thereto, and differs from the others already described in the substitution of dead pressure for impact by percussive blows.

NISBET's Machine is one of the most recent applications for this purpose, and differs from all others in two points:—First, the piston-rod is not coupled up direct to the vibrating lever actuating the pick, but to a crank-shaft, as in an ordinary engine, from which a second crank, with its connecting rod capable of adjustment as to length, so as to influence the position in which the pick will deliver its blow, thus rendering it highly effective, seeing at the moment of impact the piston is then traversing at its greatest velocity, consequently at the most effective part of its stroke; and this action is further intensified by the momentum of a fly-wheel. The shock or strain on the working parts of this machine is said to be more equally distributed than in others of similar construction.

The second point is the self-acting traversing motion along the face of the working. It is effected by means of worm and wheel gear driving a pinion working into a rack on the rail; the first motion being taken from the crank shaft by a wyper acting on a star-wheel capable of being easily thrown out of and into gear.

Having thus given a brief notice of these different boring and coal-cutting machines, I will now return to the main subject—Mr. Low's machinery for these purposes; and, before describing it, I trust I may be permitted to state what I think are the essential conditions of a good boring machine, derived from actual experience, which conditions are fulfilled in Mr. Low's new boring cylinder. These are:—

1. That the boring part, or the boring cylinder with tool, should be as short as possible, so as to allow it to transit in any direction in the tunnel, and so enable it to be set to bore at any angle, no matter how acute, and in the most favourable position and direction, so that the blast of such hole may displace the largest amount of debris.

2. That the carriage-frame carrying such cylinder should allow the same to be set easily in any position, so as to work in any direction, or at any angle.

3. That the reciprocating parts should be as few as possible, and no screws, levers, &c., should be used, as they work loose in time, and in the direct line of percussion there should not be more than the piston and rod, in one piece of steel, and the tool, which should be secured in piston so as to allow no play.

4. That the advancement of tool should be exactly in the same ratio as the tool is cutting, however variable may be the nature of the rock. For instance, in one part of the hole the tool may be cutting at the rate of 3 inches per minute, and in another 1 inch per minute; so that the tool should be fed forward self-acting, and so keep up for any of those varying rates of cutting that it may not over-feed or under-feed itself.

5. In order to prevent crystallisation of the part exposed to the direct concussion, a cushion of air should be provided if possible, at the back of cylinder, which will also relieve the carriage frame from the shocks of the blows.

6. The outer end of tool should be guided in a bearing to compel it to go straight as it bores, as a vein of quartz, &c. will invariably cause the tool to go to one side, and jam it, if not secured.

7. That the tool should reciprocate with the piston, as the hole can be easier kept free from debris than if the tool is stationary and receives blows from the piston, as experienced in the case of Westmacott's machine at Allenheads, and elsewhere.

8. The carriage frame should be so constructed that it can be brought to work again immediately after a set of holes have been blasted—a jet of air being left open near the face at the time of explosion soon dilutes and clears off the gases resulting from the explosion of the powder—and before the debris is removed, which can be done whilst the machine is at work, being carried or thrown through the machine. This will save the time, which is so much lost at Mont Cenis, removing the debris before the machine can be set to work.

9. The working parts should be as much covered as possible, to prevent wear and tear resulting from the quartz and rock dust.

10. The motion for working the valve should be effected as gently as possible, to prevent shocks so destructive, and, if possible, a steam-moved valve should be adopted.

11. The best system for rapid driving of tunnels, &c. is by boring holes and blasting, as so much time is occupied in cutting either a rectangular or circular trench, there being so much cutting ground to go through; whereas if a hole is bored in a right direction, a single blasting will displace a large amount of debris, and the smoke will be cleared in a few minutes if compressed air is used. It may be, however, found that in very soft stone, such as sandstone grit, &c., Gay's machine will drive a tunnel as rapidly, if not quicker.

12. A strong water jet should be always used to clear the hole of debris, to prevent the tool from jamming.

13. The advancing of the tool should be done without any propelling gear, such as screws, worm, and worm wheels, ratchets, levers, &c. The want of such appliances greatly increases the durability of the machine, and for this cause it is preferred to dispense with the turning gear, and turn the tool by hand.

I will now describe the first boring cylinder which Mr. Low constructed, before the present kind, and which, with its tool, is but 4 ft. 9 in. long.

The chief peculiarities are, that the cylinder is stationary (unlike all others, in which the cylinder moves), the tool being telescopic, and is propelled from the piston (by a screw which goes up inside the piston-rod) in the progress of boring, and is actuated by a diagonal slot attached to the cylinder by a roller rachet wheel. The screw, therefore, receives the blows centrally, thus obviating the danger of the tool leaning to either side. Although provision is made that the tool travels at four different rates proportionate to the hardness of the rock, this being regulated by the position of the diagonal propelling slot, which can be placed with a greater or less slope, so as to actuate either one, two, three, or four teeth, and thus to move the screw with tool more or less quickly, it required too much attention; and this, coupled with the crystallisation and gradual loosening of the screw and other parts, induced Mr. Low to construct one to do away with screws and gearing altogether, and to propel self-acting, according to the rate that the tool is then cutting, and which, I am happy to say, Mr. Low has accomplished, and according to recent trials, granite was bored by it at the rate of 14½ inches in seven minutes, and 3 inches in fifty-five seconds; and the average rate at which it bores the rock at the Dublin Corporation Water-works Tunnel, Roundwood (which is excessively hard, so much so that the miners have sometimes used from 24 to 36 tools to complete one hole 24 inches deep), composed of green hornblende interspersed with white quartz veins, is one inch per minute. The advancement of the tool as it bores requires no attention, and Mr. Low has considered it best also to do away with the turning motion, and effect the same by hand, as the very great rapidity of the blows is rather severe upon the turning motion. I may here mention that they can bore quicker, and keep the edge on tool better, by striking less hard, and to make up for not cutting so deep, the blows have been increased from 250 to 500 or 600 blows per minute; consequently, the result is that they have been enabled to bore one hole with two tools without sharpening, instead of using five or six as formerly; and with one tool a hole 26 inches deep has been bored in the Roundwood granite without sharpening.

TABLE I.

Giving the Rate of the working of the New Improved Boring Cylinder in the specimen of Granite exhibited.

Distance bored.	Time.	Trials.	Tool changed.
	FIRST HOLE.		
3 Inches	in 55 seconds.	First trial	New tool.
14½ „	„ 7 minutes.	Second „	—
7 „	„ 3¼ „	Third „	New tool
24½ Inches.	in 11 min. 10 sec.		
	SECOND HOLE.		
8½ Inches	in 7 minutes.	Fourth trial	New tool
11 „	„ 7 „	Fifth „	New tool
19½ Inches.	in 14 minutes.		

TABLE II.

Trials by the Cams slipping over Notches, each notch being 1½ inch apart, and corresponding to every 1½ inch bored.

Number of Notches.	Distance of each Notch in Inches.	Time in boring each 1½ Inches.	Changing Tools.
	FIRST HOLE.		
First Notch.	1½ inches	in 90 seconds.	
Second „	1½ „	„ 90 „	First tool.
Third „	1½ „	„ 55 „	
Fourth „	1½ „	„ 30 „	New tool.
Fifth „	1½ „	„ 45 „	
Sixth „	1½ „	„ 45 „	
	9 inches	in 5 min. 55 sec.	
Seventh „	1½ „	in 20 seconds.	New tool.
Eighth „	1½ „	„ 50 „	
Ninth „	1½ „	„ 60 „	
	4½ inches	in 2 min 10 sec.	
	SECOND HOLE.		
First Notch	1½ „	in 90 seconds.	
Second „	1½ „	„ 75 „	
Third „	1½ „	„ 100 „	New tool, but was very blunt.
Fourth „	1½ „	„ 75 „	
Fifth „	1½ „	„ 55 „	
Sixth „	1½ „	„ 60 „	
	9 inches	in 7 min. 35 sec.	
Seventh „	1½ „	in 85 seconds.	
Eighth „	1½ „	„ 75 „	
Ninth „	1½ „	„ 45 „	Longer tool.
Tenth „	1½ „	„ 50 „	
Eleventh „	1½ „	„ 35 „	
Twelfth „	1½ „	„ 35 „	
	9 inches	in 5 min. 25 sec.	

The average rate at which the machine bores the excessive hard rock at Roundwood is one inch per minute.

I might also mention that a hollow tool has been tried, into which was inserted a water-jet, and also having the exhaust from the cylinder turned into it, which forced the water at a considerable pressure out at the point of tool in the hole. This was found a most excellent plan for keeping the hole clean; but in consequence of its complication it was abandoned for a separate water-jet.

NEW BORING CYLINDER (Plate 21)—This machine is represented in the several partly sectional Figs. Nos. 1 to 8, where Fig. 1 and 2 show the cylinder and boring arrangement; Fig. 3, the motion for turning the boring tool; Fig. 4, a section of the disc valve, taken on the line A B, Fig. 1 and 2; Fig. 5, sections taken at C D and E F; Fig. 6, sections at G H and J K; Fig. 7, sections at L M and N O; and Fig. 8, sections at P Q and R S.

It is only 4 ft. 9 in. long, and the working cylinder, constructed of brass, A, is placed inside another cylinder of wrought-iron B, in which it is free to move from one end to another, and also to rotate. The back end of the cylinder A, is packed with india-rubber, metallic, or other suitable rings C, so as to be air or steam tight. The front end fits into a wrought-iron cross-head

D, in which it is free to revolve. This cross-head is slotted on each side to fit into two slide-bars E E, carried from cylinder to end bearing of machine, along which it slides as the cylinder A is moved along inside the cylinder B in the process of boring. The sides of the above-named cross-head D, where it fits into the slide-bars, E E, is projected in front on each side of the slide-bars E E, between which is placed two cam-bars, F F, partly forked on each edge of slide-bars. The other end of the said cam-bars F F, rests in notches G G, cut at intervals of 1½ inches from each other on the inner side of the slide-bars E E, and are constantly kept pressed against the bottom of the said notches by two spiral springs of steel wire H H. The other end of the cam-bars F F, which work on centres I I, are so curved towards each other at L, that the end of piston-rod may strike them at the proper time. The operation may thus be explained:—The air, steam, or other motive fluid is admitted by the pipe K—which leads from one of the trunnions—into the wrought-iron cylinder B, behind the back end of the working cylinder A, and thus keeps it pressed outwards against the cross-head D, which is kept in its place or from going forward by the two cam-bars F F, each of which rests against one of the notches G G in the slide-bars. It will thus be seen that when the tool has advanced 1½ inches into the hole, the end of piston-rod (the end of which is allowed to go 1½" beyond its limit) comes into contact with the cams or curved end of cam-bars F F, at L, and thus causes them to slip over the notch into the next, and this is repeated for every 1½ inch bored till the end notch is reached. This will allow the tool to advance at whatever rate it is cutting, *i.e.*, when the tool cuts rapidly, the cams will slip from one to another rapidly; whilst, when the tool cuts slowly, the cams will be so much longer in slipping from one notch to another.

On the two cam bars FF, are two diagonal wedges, MM, which are pressed forward by spiral springs between the teeth of slide bars and cam bars. This is to steady the cam bars, and keep them in the positions to which they are raised by the end of piston-rod at each blow, and prevent the spiral springs HH, from pulling the cams to the bottom of the notches. When the cam bars slip over, the ends of the diagonal wedges come against the next teeth of notches, and are pressed back into their normal positions again.

The cross-head D is provided with two copper breaks N N, pressed upon the side of slide-bars by a powerful spiral spring regulated by a screw fitted with double handles O O, for the purpose of enabling the break to be regulated by hand. This is to prevent the cylinder with cross-head and cam-bars from slipping too violently from one notch to another. The above double handles O O, serve also to pull back the whole by hand when necessary to change the tool.

The chamber into which the air is admitted into the iron cylinder B, and behind the cylinder A, serves to contain a portion of air to act as a cushion to prevent crystallisation of the parts exposed to the direct concussion of the blows, and also to relieve such shocks upon the carriage generally.

At the back end of working cylinder A, is the circular valve P, with six or more inlet ports and six or more exhaust ports. This valve is turned by a double spiral cam Q, which is carried into end of piston and rod, in which are four rollers RRRR, which bear on both sides of the spiral wings of the cams Q. These spiral wings are so sloped that upon the reciprocation of the piston it is gently turned or twisted, and with it the valve to which it is connected. The slopes on spiral wings of the cam Q are so placed as to cause the valve P to open the inlet ports, to admit air to act upon the large area of piston, and to allow it to exhaust again after the piston has struck a blow, when it will return, by a constant pressure upon the small area maintained, through the two ports XX, and *vice versâ*.

The piston is prevented from turning in the cylinder by means of two flats, planed on each, which fit into corresponding flats on the bush and stuffing glands of cylinder. The rotary motion of cylinder A, with piston and tool, is effected by a square bar S, working inside the cam or spiral bar Q, which receives the same turn at each stroke of piston as the valve. On the end of the square bar, outside the end of cylinder B, through which it is carried, is a double lever T, at each end of which are two pawls, working into a ratchet wheel U, on end of shaft V, and are so arranged as to give a continuous motion to the same. This shaft V, is provided with a square part, on which is a brass pinion wheel W, which works into a geared portion of working cylinder A at Y, and so causes it to rotate with the piston and tool by the ratchet U aforesaid. On end of shaft V, the brass pinion slides along the square part of shaft V, as the cylinder A advances by the cams FF, slipping over the notches.

It is however preferred, as aforesaid, to turn the shaft V, by hand, either by means of a hand-wheel and mitre-wheel working into a mitre-wheel on shaft V, or by double levers with pawls, giving a continuous motion to the two ratchet-wheels on shaft V. At the end of the two slide-bars EE, are two screws with steel points ZZ, for the purpose of steadying the end of machine against the rock. The end of the tool is steadied in a bearing JJ, across the end of the two slide-bars, in order to compel the tool to bore straight, and it is so arranged that upon turning the lever C, the top bearing or step can be easily lifted out when the tool requires changing.

(To be continued.)

PREVENTION OF RAILWAY ACCIDENTS.

The class of railway accidents that are caused by negligence or malice seem more fearful than those that occur in consequence of defects in mechanism or from badly-arranged signals, because they are more removed from control, and may happen though every ordinary precaution is taken to prevent them. The accident at Staplehurst was one of that kind. The South Eastern Railway has enjoyed the reputation of being safer than any other. It was on that line that, in the early days of the electric telegraph, the company availed themselves of the invention by forming a complete system of telegraphs from station to station, the entire management of which they took into their own hands, for the purpose of avoiding any interference with their railway signals. It was the practice not to allow any train to start from one station until a signal had been received from the next, indicating that the line was clear, and active telegraphic communication was constantly maintained to avoid collision and to give notice when any obstruction was on the lines. Even these precautions have not always proved sufficient to prevent collisions, of which there was an instance, some time before the accident at Staplehurst, when one train ran into part of the preceding one, that had become detached by the breaking of a coupling chain. Defect in the mechanism and negligence combined to produce that disaster, which showed that no system of stationary signals is sufficient to insure the safety of railway travelling. Each train, and every carriage of a train, ought, as far as possible, to be provided with the means of self-protection. The instant that danger is perceived, those in charge of the train should be able to slacken speed or bring it to rest within the least possible time that it can be done without sudden shock. The passengers in every carriage ought to have the means of signalling to the guard or engine-driver the occurrence of any incident that may occasion damage either to themselves individually, or to the carriage in which they are shut up. That they should be allowed the power of escape seems to be generally admitted by all but railway officials, and until the plan be adopted —which there are several contrivances to carry into effect—of simultaneously putting breaks on to the wheels of every carriage, each one ought to be provided with the separate means of checking speed, under the control of the passengers. We place not the least value on the objections raised to giving power to passengers to act in self-defence, on the ground that the power might be abused either wantonly, ignorantly, or foolishly. Punishments adequately severe would soon put a stop to inconveniences that might arise from the ill-judged or wanton action of individuals, and nothing ought to be left undone that can add to the security of railway travelling.

But no precaution within the range of mechanical arrangement would have prevented such an accident as that at Staplehurst. It is in the power of any man to upset a railway train, if, regardless of all consequences to himself, he wilfully removes one of the rails when a train is about to approach. A system of supervision so close as to prevent the possibility of such a malicious act can scarcely be attainable, and even if it were established, what security would there be against the possibility of one of the inspectors appointed to watch the line being himself the offender? When men employed by the company to repair the line, take up the rails at the time a train is due, what reliance can be placed on a system of supervision to prevent others from doing the same? We believe that the real and most effectual means of prevention is the employment of agents of a superior class, well acquainted with the duties to be performed, and fully aware of the responsibility of their positions, and adequately remunerated. It was well observed by Mr. Edwin Chadwick, in a lecture recently delivered at the Royal Institution, on the wage-classes in England, that the highly responsible situations which have been created by the progress of invention, ought to be filled by men of a higher grade in society than those to whom they are now entrusted; or rather, that the situations should be elevated in social estimation, so as to induce educated gentlemen to become candidates for them. The progress of improvement in all kinds of manufacturing industry has been more rapid than the progress of education; and we are in the position of requiring a large amount of skilled labour of the highest kind, involving in its exercise great responsibility, and without having a class of men properly educated for doing the work. Those are placed in positions, in which the lives of hundreds of persons may depend on the proper discharge of the duties to be performed, who are in the social scale not placed above ordinary labourers. This ought not to be. The payment of higher salaries might do much to remedy the evil, by inducing those who have been educated with a higher sense of moral responsibility, and who rank as gentlemen, to undertake such work. The railway companies would, as a mere question of economy, find it to their advantage to raise the social estimation of the officers they employ, so as to be able to engage men who are more trustworthy and who are fitted to discharge the onerous duties imposed on them. It is to such an improvement in the character of the staff of railway officials, that we must look for the avoidance in future of accidents similar to that at Staplehurst.

The other accident of a similar kind, that happened to an excursion train near Shrewsbury, was attributable rather to the carelessness of the engine-driver and to the hazardous incidents that will occur to trains that run at irregular times, than to negligence of the plate-layers. The greater part of the damage and loss of life, on that occasion, might have been averted by the adoption of a contrivance that may be seen at the Polytechnic Institution, by which an engine that runs off the rails becomes immediately detached from the train of carriages, which are consequently not dragged after it to destruction.

BOSHAM CHURCH, NEAR CHICHESTER.

To the historian and the archæologist, the village of Bosham, situated a few miles to the westward of the city of Chichester, is a place of considerable interest. It was a place of some importance in the earliest times of which we have record, and is more than once mentioned in the old Saxon chronicles. The Saxon kings lived here, and the remains of an old forest still passes by the name of Old-park. Canute's daughter was buried in Bosham Church; and it is most probable, that if the story of Canute's lecturing his courtiers on the sea-shore be true, the incident took place here rather than at Southampton. This was the first place upon the Sussex coast in which Christianity was taught, for when Wilfred landed at Selsey, about the year 680, he found a poor monastery already existing at Bosham. It was from this place that Harold started when he visited Normandy; and Bosham Church makes a conspicuous feature near the commencement of the Bayeux tapestry. It had long been acknowledged that the tower of Bosham Church was a Saxon work, and that it was the highest tower built at that period in the kingdom; recent discoveries show that there is a great deal of undoubted Saxon work in other parts of the building. An effort was made, some little time since, to restore the church, as by the neglect of ages it had been allowed to fall into a state of comparative dilapidation. The Ecclesiastical Commissioners promised to restore the chancel if the other parts of the edifice were put into a proper state by the parish, aided by such subscriptions as could be obtained. The restoration of the chancel was accordingly carried out under Mr. Christian, architect, of London.

The timber roof of the nave and aisles was in a bad condition; it was therefore taken down and replaced by a new one, which has of course been carried up to its original pitch, the one it replaces having been much lower. In doing this some Saxon windows were discovered on the east face of the tower, and they have been opened. The plastering and whitewash with which the walls of the church had been defaced have been cleared away, and it is evident that the stonework of the nave above the lower arches is of Saxon date, as are the clerestory windows which have been discovered on the north side. At the angles immense blocks of stone are used, in the manner known as "long and short work:" the other parts are built of small stones. There is some herring-bone work, and many Roman tiles are built into the walls. There must have been several chapels within the building, the aumbreys, piscinas, brackets, &c., having been brought to light in the course of the work. At the east end of the north aisle a pillar piscina was discovered. The drain connected with it was found to be choked up, and in clearing it out an old and rusty knife was found, and beyond that three small silver coins, one of them of the date of Edward I. At the west end of this aisle, the lower jaw of a very old person and one or two other mouldering fragments of bone, were found hidden in a cavity in the wall. There is a small crypt, several interesting monuments, a Saxon font, a very old chest, some good carved woodwork, and other things of interest about this church. The work of restoration is still going on, under the management of the vicar, the Rev. H. Mitchell, F.S.A., and the committee.

CHURCH OF THE RESURRECTION (ANGLICAN), BRUSSELS.

(With Engravings.)

The increasing number of English residents in Brussels, and especially of the congregation, members of the English Church, using the chapel of the Museum, Place Royale, has long since rendered it necessary to seek a better location. The enormous price of land in the vicinity of the Quartiers Leopold and Louise, in which it was necessary to erect any new church ultimately decided upon, for a long time baffled all hopes of success. In the autumn of 1863, however, a site fortunately presented itself, being a large garden in the Rue des Drapiers, Boulevard de Waterloo, and which was at once purchased by the committee; the frontage was allotted into building plots, and the rear retained for the site of the church; thus reducing the cost of the land. The site stands north and south, and consequently the ritual east end is due south. A new boulevard is in contemplation on the west side of the church, which will greatly enhance the value of the position, and exhibit that portion of the church shown in the view.

The church is being built of the Boom bricks, made near Antwerp; they are small in size, being 7½ inches long, 3¼ wide, and 2 inches thick, and are generally used in all works at Brussels. The external face of walls, including all door and window jambs, and arches, will be likewise formed in the same material, which is of a warm red colour.

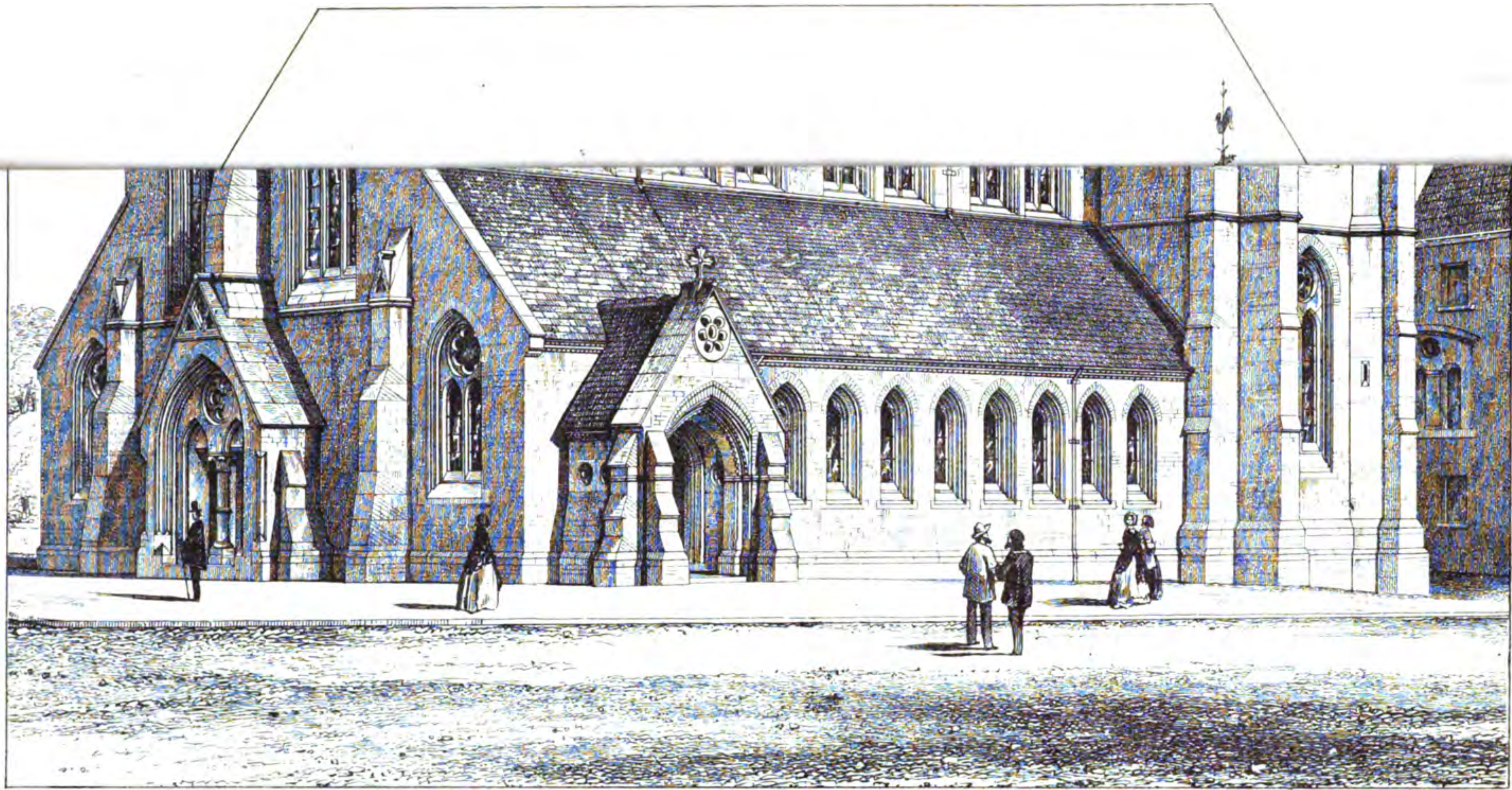
The stone for all purposes will be that known as "Vergolet fin" and "Banc Royale St. Waast," from the celebrated quarries at Criel, Oise, France, and it is intended to use the native red Luxembourg marble wherever practicable. The roof will be framed in Memel timber, and covered with very small and pretty local slates (10 by 6) of a warm green colour.

The plain faces of walls alone will be plastered internally, everything else being formed in stone. It is hoped to be able to pave the entire area with Minton's tiles, and to have low moveable benches in the nave only, chairs being used elsewhere.

The dimensions of the church, in Belgian measure, are as follows:—nave, 22·10 by 9·46 metres; north and south aisles, 22·10 by 2·10; chancel, 8·52 by 7·90; tower, 4·21 by 4·21, internally. The height of aisle walls is 4·56, and of clerestory walls from nave floor 12·50; the height of ridge of nave roof is 19·75; and of chancel ditto, 16·84. The tower and spire above lower stage will be omitted for the present, as also the side porch.

The use of polychrome incised stonework and painted glass will be dependent upon special donations. It is desired, by all concerned to render this church a pattern of an *English* church, where our countrymen, who are expatriated for a time, for educational or other purposes, may enjoy the services of the church of their fatherland the same as at home—a comfort seldom enjoyed abroad.

The architect of the church, and under whose superintendence it is now being erected, is Mr. R. J. Withers, of Doughty-street, London.



J. R. Jobbins

CHURCH OF THE RESURRECTION (ANGLICAN)

RUE DES DRAPIERS–BOULEVARD DE WATERLOO,

BRUSSELS.

NORTH WEST VIEW.

R. J. WITHERS, ARCHITECT, LONDON. 1864.

THE WEAR AND TEAR OF STEAM BOILERS.*

By FREDERICK ARTHUR PAGET, C.E.

THERE is, however, another very important point with respect to wrought-iron, which has scarcely received the attention it deserves. As would appear from a number of phenomena, there seems to be a sort of thermal elastic limit with iron. When heated, and when its consequent dilatation of volume does not exceed that which corresponds to (perhaps) boiling point, it returns to its original dimensions. Beyond a certain temperature it does not contract again to its pristine volume, but takes a permanent dilatation, in consequence, apparently, of its elastic limits having been exceeded. A number of observers† have determined the fact with cast-iron, and though wrought-iron has not been expressly investigated in this direction, there is no doubt that it exhibits a similar behaviour. Thus, a number of years ago,‡ an Austrian engineer, named C. Kohn, remarked that a boiler about 12 metres long and 1·57 in diameter, with a thickness of plate of 0·011, permanently expanded, at a temperature corresponding to a steam pressure of five atmospheres, (153° C.) by 0·07193, and did not, when cold, return to its original dimensions. The same thing has been noticed, by means of very accurate measurements, with other boilers. A number of experiments by Lieut.-Col. H. Clerk, of Woolwich, on wrought-iron cylinders and plates,§ bear distinct evidence to a dilatation of volume in wrought-iron, when repeatedly heated and suddenly cooled. In experiment 7, for instance, "two flat pieces of wrought-iron, each 12 inches long, 6 inches deep, and ½ an inch thick, were heated and cooled twenty times, one being immersed to half, and the other to two-thirds, its depth in water. That immersed one-half contracted or became indented on the ends fully ·3-inch; the other had similar indentations, but only to one-half the amount. They both turned up into the form of an arc, the *convex* side of which appeared in the portion heated and cooled. Unfortunately, the specific gravities of the different portions were not tried by Colonel Clerk. A succession of trials of the kind produced cracks in the metal, thus explaning how boiler plates are cracked by imperfect circulation and by cold feed-water let in near the fire; and, the thicker the plate, the more permanent dilatation of volume and consequent danger. Mr. Kirkaldy found that, "iron highly heated and suddenly cooled in water, is hardened," being injured, in fact, if not afterwards hammered or rolled. This permanent dilatation of volume must be necessarily accompanied with a diminution of specific gravity, thus affording another close analogy between straining iron by loads in excess of the mechanical elastic limits, and straining by heat. Lajerhelm‖ found long ago that the specific gravity of iron is diminished by strains in excess of the limit of elasticity, and this result has been completely confirmed by Mr. Kirkaldy's numerous experiments. The smith calls iron "burnt" which has been rendered brittle in working through the often repeated applications of heat, or through too high a temperature. Iron rendered brittle by strains in excess of the limit of elasticity has been long popularly termed "crystallised." Both these states are accompanied with a dilatation of volume and attendant hardness and brittleness, and both seem to be referable to very similar causes. In fact, a very general belief exists that very ductile good iron, used in the form of a steam boiler, soon gets brittle. There are some applications of metal to a steam boiler peculiarly liable to be strained beyond the limits of elasticity, by mechanical force of expansion and contraction, and by dilatation of volume through heat—all three acting simultaneously. Such is the case with fire-box stay-bolts. Accordingly, they are found to get very brittle when of wrought-iron, which is a much less ductile metal than copper. Mr. Z. Colburn states that he has "frequently found these stays (where made of wrought-iron) to be as brittle, after a few year's use, as coarse cast-iron." He has "broken them off from the sides of old fire-boxes, sometimes with a blow no harder than would be required to break a peach-stone." ¶

THE CHEMICAL EFFECTS OF THE INCANDESCENT FUEL.

Whatever physical changes may be induced in iron by the long continuance of a high temperature which is not succeeded by the application of the impact of the hammer or the pressure of the rolls, it is certain that long-continued red heat leads to the loss of its metallic consistency. Its surface gets converted to a greater or less depth into forge scales, which, according to Berthier, consist of a crystallised compound of peroxide and protoxide of iron. The mechanical action of the gases—and especially of the free oxygen contained in every flame—forced at a high velocity by the draught past the more or less heated plates, would also aid these chemical combinations—upon the same principle as iron filings, thrown through a gas flame, burn in the air; and upon the same mechanical principle as the incandescent lime is worn away by the flame of the oxyhydrogen blow-pipe. These actions would take place with any fuel, even with pure charcoal. But when mineral fuel, which mostly contains more or less iron pyrites, is used, there is much more danger to the plates, especially over the fire, in getting red hot, as the flames would then hold sulphurous acid, and often volatilised sulphur. A familiar illustration of an action of this kind is afforded by the fact that a piece of red-hot iron plate can be easily bored through by means of a stick of sulphur, the combination forming sulphide of iron. Dr. Schafhaeutl, of Munich, has given great attention to the changes in plates subjected to the action of fire; twenty-five years ago he read a paper before the Institution of Civil Engineers,* and more recently he has published an essay, both on this subject, in a Munich periodical.† He has brought forward a number of facts, founded on chemical analyses of plates of exploded boilers, showing the danger, due to chemical action alone, when the plates of a boiler become red hot. He notices that the iron of the inside of the plates, in getting red-hot, decomposes the water, and combines with the oxygen thus freed. It also loses some of its carbon. The outside combines with the free oxygen and with any sulphurous acid in the flame. He states that iron made with pit coal is much more affected than charcoal-made iron; becoming laminated at the original joints in the pile out of which the plate has been rolled. It is possible that portions of oxide are carried into these joints, and it is at any rate certain that iron gives way easiest at these places. This points to the great value of really homogeneous plates, such as those of cast steel, in which homogeneity has been obtained by the only known means of fusion. The remarkable diminution of elasticity and of tenacity caused by the combination of the red-hot iron with sulphur; the absence of all elasticity and tenacity in the oxides of iron, show that, even if a flue do not at once collapse, or a shell explode, through getting red-hot, the boiler is more or less injured every time it gets overheated. A defective circulation, by permitting such a temperature as to drive the water off the plate, would soon lead to local injury. Particular spots in externally fired cylindrical boilers are sometimes, as is stated by Mr. L. Fletcher, of Manchester, thus affected, and in an apparently mysterious way. A new boiler, in which a heap of rags were accidentally forgotten, had the spot burnt out in a few days,‡ doubtless through the resulting defective circulation and its consequences. The plates just above the fire of internal flues also suffer in this manner. It is perhaps possible that turned joints, secured by bolts, and allowing an occasional reversing, or rather rotating of the ring, might, in some cases, be here of service. At any rate, universal experience proves that the thicker the plate the easier does it get red-hot; and these chemical facts also point to the desirability of a minimum of thickness. In fact, the wearing away of the plates through these causes, if mechanically strong against pressure, often gets arrested at a certain thickness. In Germany and France, some of the best manufacturers still make the plates over the fire of, for instance, insideflues, slightly thicker than anywhere else; but the combined chemical and mechanical actions of the heated fuel cause most wear and tear in a thick plate, and thus justify American practice in this respect. In that country, fire-box plates of good charcoal iron are made only $\frac{5}{16}$ or ¼ of an inch thick; and, with stays 4 inches apart, give good results under nearly 150 lb. steam pressure.

THE CHEMICAL AND PHYSICO-CHEMICAL EFFECTS OF THE FEED WATER.

The wear and tear of a boiler which occurs in the form of corrosion, properly so-called, may be divided into two principal kinds—1. internal; and 2. external. The progress of both is necessarily intensified by the mere effects of temperature; each,

* Continued from page 186.
† Percy's Metallurgy, Vol. 2, p. 872. ‡ Technologiste. 1850-51, p. 102.
§ Proceedings of the Royal Society, March 5, 1863.
‖ Poggendorf's Annalen, 2s., vol. 2, p. 468. ¶ Steam Boiler Explosions, 1860, p. 32.

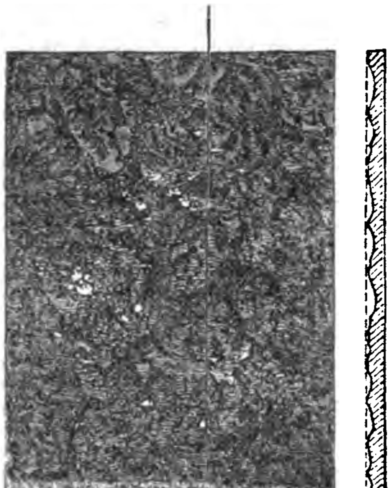
* Transactions of the Institution of Civil Engineers. Vol. iii. 1840; p. 486.
† Bairisches Kunst und Gewerbeblatt. June, 1863.
‡ Péclet, Traité de la Chaleur. Vol. ii., p. 72.

however, has its strongly-marked distinct character—not merely as to position, but also as to origin and results.

A steam boiler is in the position of a vessel into which large volumes of water are continually forced; while the heat applied, driving off all volatilisable matter, leaves behind a concentrated solution with a chemical character dependent on that of unvolatilisable matters in the feed water. The specific gravity of the substances found in the water naturally causes them to sink towards the bottom, at which part the solution is generally more concentrated, however much it may be stirred up by the ebullition. Mr. J. R. Napier lately stated that a piece of zinc, "about 4 feet long, by 3 inches broad, by 3-16ths thick, placed in a marine boiler for three weeks," to a depth of 18 inches in the water, showed a corrosion which rapidly decreased up to the highest part, which, in the steam, appeared to be little affected.* This accounts for the fact that all boilers, even those internally fired, like locomotive boilers, have their plates most affected towards the bottom, and that internal corrosion always shows itself to a greater extent below the water line. The *bouilleur* of the form of boiler known as the French boiler, is also generally more affected than any other part. To resist this sort of slow action, it is clear that the more the bulk of metal the better, and it is for this reason that the bottom plates of most marine boilers are made thicker, while these same plates in locomotive boilers have to be often renewed. Any chemical or physico-chemical action of the kind is of course intensified by temperature, and this is one of the causes why externally fired boilers give way most a little in front of the furnace. But the plates above the water-line also get more or less corroded, and not merely with the usual character of rusting, but in that peculiar form known as pitting, which generally shows itself much more strongly marked below the water-line.

The presence of a concentrated solution of an acid or alkaline character, kept at a high temperature for years in contact with iron plates, would be sufficient to account for much corrosion. But the internal corrosion of steam boilers has many features of such a mysterious character, that no accredited explanation of its attendant phenomena has yet been put forward. In the first place, plates thus attacked show a number of irregular holes, like a pock-marked human face, or like the small craters seen on the

FIG. 4.



The internal surface of a plate of an old wrought-iron boiler, showing, one-quarter of the full size, the ordinary appearance of pitting.

moon's surface. (See Fig. 4.) The writer has also sometimes observed two or three little irregular excavations like this in a plate otherwise showing a large surface quite intact. Sometimes the plate is most pitted round a projecting bolt; at others, one plate will be perfectly sound, while that rivetted to it will be almost eaten away, both having been the same time at work, and under, of course, apparently similar conditions. With locomotive boilers this pitting has been ascribed to galvanic action between the brass tubes and the iron plates. But it is notoriously well-known to locomotive superintendents, that boilers with iron tubes are often worse pitted than those which have run the same distance with brass tubes. Besides, all iron boilers, with or without brass, whether used for stationary, locomotive, or marine purposes, are subject to pitting.

An explanation which seems to meet all the circumstances of the case is the following:—Mr. Mallet, in a report addressed to the British Association some years ago, showed that wrought-iron and steel (blister steel probably) consist of two or more different chemical compounds, coherent and interlaced, of which one is electro negative to the other. In fact ordinary wrought-iron, being also welded up from differently worked scrap, is far from being an electro-homogeneous body. In a boiler, the hot water more or less saturated with chemical compounds, is the exciting liquid, and the electro-positive portions of the plates are thus quickly removed to a greater or less depth. This explanation meets most of the known circumstances with respect to pitting; it even, in a great measure, explains how plates above the level of the water, especially in marine boilers, get very rapidly corroded in portions, while another part of perhaps the same plate is scarcely affected. The concentrated water in a marine boiler, is known to be generally acid. "Of all the salts contained in sea-water," says Faraday,* "the chloride of magnesium is that which acts most powerfully" on the plates. He shows that a cubic foot of sea-water contains 3·28 oz. of this salt; and at the same time, points to the danger of voltaic action in a boiler through the contact of copper and iron. In a smaller degree, the contact of cast with wrought iron, or between the different makes of wrought-iron in the same plate, or between contiguous plates, acts in the same way. It is not improbable that some hydrochloric acid is present in the steam of marine boilers. Mr. J. C. Forster† has tested some of the condensed steam from the safety-valve casing, and from the cylinder-jacket, of the Lancefield, and found both decidedly acid."‡ With an exciting liquid in the condensed steam, it is thus explicable how the plates of marine boilers often get corroded in a most capricious manner; while, at the same time, the current of steam would create a certain amount of friction on the oxide, clearing it away to act on a fresh surface.

The crucial test of this explanation of pitting would be the observation of the absence of the phenomenon from plates of an electro-homogeneous character. This homogeneity could only be expected from fused metal, such as cast-steel. Accordingly, while the writer was in Vienna a short time ago, he was assured by Mr. Haswell, the manager of the Staatsbahn Locomotive Works, that some locomotives made of cast-steel plates in 1859, for the Austrian Staatsbahn, had been working ever since without showing signs of pitting, though under similar conditions iron plates had severely suffered in this way. Pitting may thus be fairly defined as a form of corrosion localised to particular spots by voltaic action. It is also probably aggravated through the motion of the plate by mechanical action, and the expansions and contractions through alternations of temperature. All boilers are most pitted near the inlet for the feed water, and with inside cylinder locomotive boilers there is generally more pitting at the smoke-box end—no doubt caused by the more or less racking action on these plates. A state of corrosion at particular spots would probably be kept up to a greater intensity by the incrustation being mechanically thrown off. With a quicker voltaic action, caused by any unusual intensity of the exciting liquid, the sides of the cavities in the plates would be sharper and less rounded off; as in the case of the boiler fed with mineral water from ironstone workings, which exploded last year at Aberaman, South Wales. (See Fig. 5.)

The fact that pitting occurs in marine boilers when distilled water from surface condensers is used, does not affect this explanation. Water distilled in this way, from whatever cause, after repeated boiling, is stated to carry the salinometer even higher than sea-water, thus proving that it is not pure.§ In the next, there is the absence of incrustation, which to some extent always protects the plates of boilers from the chemical action of

* Institution of Engineers in Scotland, Session 1864—5.

* Fifth Report of the Committee of the House of Commons concerning the Holyhead Roads, p. 194.

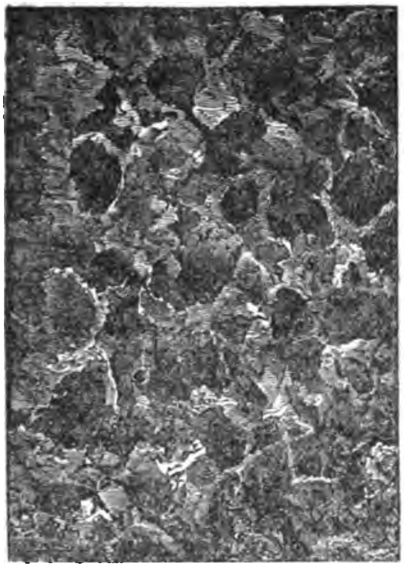
† Institution of Engineers in Scotland, 1864-5. Introductory address by Mr. J. R. Napier.

‡ When a solution of chloride of magnesium is evaporated nearly to dryness, the salt and the water are decomposed, magnesia and free hydrochloric acid being formed; or $MgCl + HO = MgO + HCl$.

§ Institution of Mechanical Engineers, 1863. Discussion on Mr. James Jack's paper "On the Effects of Surface Condensers on Steam Boilers."

its contents. In this way the mechanical buckling of the plates—directly and indirectly causing the furrows we have spoken of—by continually clearing particular lines of surface from incrustation and oxide, reduces these particular spots, with respect to corrosion, to the condition of the plates of a boiler fed with water which deposits no incrustation. Corrosion will also act more

FIG. 5.



From a photograph of surface of corroded plate cut from one of the two boilers that exploded on Wednesday, February 17th, 1864, at Aberaman Iron Works, Aberdare. The corrosion was internal, and in some parts the plate was not more than one-eighth thick. Thirteen persons were killed, and many others seriously injured.

rapidly at a furrow through mere increase and renewal of surface. To resist that form of internal corrosion specially known under the name of pitting, a maximum of electro-homogeneity is evidently required in all the component parts of the boiler.

While the action of internal corrosion, often very equally corrugating the plates over a large surface, as a rule scarcely, at any rate only gradually, affects their mechanical strength, external corrosion, being localised to particular spots, is of a much more dangerous character. The one is gradual and easily perceptible, while the other is rapid and insidious in its progress. Apart from accidental circumstances affecting the brickwork on which a stationary boiler is erected, or the outside of the bottoms of marine boilers, it is clear that external corrosion can only occur through leakage. When leakage takes place through a crack in the plate caused by mechanical action, or at a hole burnt out by heat, the effects of leakage are only secondary results, due to a primary cause which of itself may cause the stoppage of the steam generator. But a leakage at a joint may in itself gradually cause the destruction of the boiler. Here we see another reason that the character of a boiler, not merely as to ultimate strength, but also as to wear and tear, intimately depends upon the form of its joints. It is often noticeable that very good lap joints, even when tested under hydraulic pressure up to only 50 per cent. above the working load, sweat more or less. The tendency of the internal pressure to form a correct circle bears indirectly on these joints, causing them to open, more or less, and to leak in spite of the caulking. Mr. Robert Galloway, C.E., who, as an Engineer Surveyor of long standing of the Board of Trade, has probably made more than three thousand careful inspections of marine boilers, states that he has often noticed a furrow or channel on the outside of the joint, running parallel to the outside overlap for some distance, and evidently caused by leakage. Along the water line, condensed water will act on the joints, while below it the concentrated contents of the boiler will come into chemical action. A leakage in a marine boiler often eats away a plate within a year. In some cases a jet of hot water from a leakage has a frictional action; in fact, even with such an incorrodible and hard substance as glass an effect like this has been perceived, and a slight leakage continued during several days sometimes produce a noticeable furrow on a glass gauge tube. With sulphurous fuel, a powerful chemical action will come into play on the plates. One volume of water takes up about thirty volumes of sulphurous acid gas; and these sulphurous fumes of the fuel, coming into contact with the water from a leakage, will be more or less absorbed. An acid solution like this must quickly eat away the plate. It is certain that a leakage acts much quicker on a boiler fired with sulphurous fuel than on one fired with wood. M. G. Adolphe Hirn has observed a plate, nearly ⅞ths thick, to be pierced, in the course of time, as with a drill, by means of a little jet which struck it after passing through a current of hot coal smoke.*

LEGISLATIVE ENACTMENTS.

No stronger proof can be adduced of the empirical state of existing knowledge of the management of boilers than that afforded by a consideration of their average duration. While some marine boilers last only about three years, there are carefully worked land boilers which have lasted as long as thirty. Captain Tyler, R.E., estimates the average duration of a locomotive boiler at from five to twenty years. Perhaps the average duration of a marine boiler may be reckoned at from five to seven years; that of a locomotive boiler at from eight to nine years; that of a stationary boiler at from eighteen to twenty years—all being supposed to be fairly worked under ordinary conditions.

It is clear that, subjected as a steam boiler is to so many destructive influences, the precise effects of which can scarcely be yet very accurately known, the working tension should be only one-eighth of the ultimate bursting strength. But when boilers, as is too often the case in England, are bought by the weight; when cheaply paid labour is employed in their management; when inspection of the progress of the wear and tear necessarily happening even with good boilers and good attendance, is procrastinated for the sake of gain, there is then a suit of expense *versus* risk, in which parsimony too often gains the day. At any rate, a number of painful accidents in all parts of the world have, at different times, pointed to the fact, that every man picked at hap-hazard cannot be safely trusted with steam-power. In fact, there is probably no civilised country in which the legislature has not more or less interfered in the management of steam boilers. In the United States of America the frequency of boiler explosions has in some localities produced a more despotic interference than perhaps anywhere else. In the city of New York, boilers are under the supervision of the municipal police; they are tested periodically, and as a result, many are condemned every year. By an enactment of congress, applicable to all the States,† steam passenger vessels are subjected to government inspection. The 13th section of this act shows a very acute perception of the real cause of a boiler explosion, which, it states, shall be taken as full *primâ facie* evidence of negligence on the part of the owner, upon whom is thus put the onus of disproof. The law of Louisiana‡ is particularly severe, requiring the application of a hydraulic test threefold that of the working pressure. Of course, there is a great distinction between enacting a law and putting it into practical execution, and it is probable that laws like these could only be carried out by organised bodies of police, like those on the continent. In France, in 1810, 1825, 1828, 1829, 1830, 1843, and lastly on the 25th of January, 1865, as many different regulations have been issued with respect to steam boilers of all kinds. Beginning by requiring that every boiler, even of wrought-iron, should be submitted to a hydraulic test of five times the working pressure, in 1843, and lastly to a twofold pressure; this has been successively lowered down to a threefold pressure, by the Imperial decree of this year.§ The previous law fixed the minimum thickness of the plates—a regulation which undoubtedly did much injury to boiler making in France. The old Prussian regulation of the 6th of May, 1838, also fixed the thickness of the plates, but did not require any hydraulic test. By the Regulativ‖ of the 31st of August, 1861, this was completely altered. The construction of the boiler was left entirely in the hands of the maker; but stationary boilers had to withstand a threefold, and locomotive boilers a twofold, hydraulic pressure. In the same way as with the present French law, the test had to be repeated after any considerable repairs. On the 5th of March, 1863, a ministerial decree reduced the testing pressure for old locomotive boilers down to 1½ of the working

* Bulletin de la Société Industrielle de Mulhouse, 1861, p. 558.
† Session of Congress, July 7, 1838.
‡ Baltimore American, 1835.
§ Décret concernant la Fabrication et l'Etablissement des Machines à Vapeur. 25 Janvier, 1865.
‖ Düsseldorfer Zeitung. 24 September, 1861.

pressure; and another Circular Erlass, published on the 1st of December, 1864, reduced the test for all kinds of boilers down to twice the working load. There is now no material difference between the French and the Prussian regulations respecting boilers; and it may be expected that those continental states, such as Russia, Switzerland, and Spain, which have more or less copied the old French law of 1843, will also adopt the present alterations. There is also some talk about altering the present Austrian law,* which determines the thickness of the plates, but only demands a double pressure test. The Belgian *réglement* † also requires double the working pressure for common boilers, but only 1½ for tubular boilers. According to Article 31, the test must be annually applied to locomotive, portable, and marine boilers, as also after all considerable repairs. There does not seem to be any general law in Italy, but in the special acts authorising railway companies, similar requirements to the French regulations are laid down, and government commissioners see that they are carried out. Each of the smaller German states also has its law, more or less like that of France and Prussia. Mecklenburg-Strelitz‡ requires that common boilers be proved to three, and tubular boilers to twice the working pressure; to be renewed every fourth year, and every time that the boiler is repaired or altered; Saxony,§ that cylindrical boilers be tried to twice the working pressure, and tubular boilers to a pressure three atmospheres above it. Bavaria || now requires double the working power pressure for new, and one and a half for old boilers; while both Hanover and Brunswick each have a somewhat similar regulation.¶ The French law, and indeed most of the others, require two safety valves; and many are extremely minute in their directions with respect to glass gauges, steam gauges, and other fittings. In Great Britain there are no express legislative enactments with respect to boilers beyond those stated in two clauses of the Merchant Shipping Act,** according to which—1. one safety-valve in every boiler of a vessel carrying passengers shall be placed beyond the control of the engine-driver; and 2. any overloading of this valve is made punishable by a fine of not more than £100, in addition to any other liabilities which may be incurred by such an act. The boilers of all vessels carrying passengers, before clearing out of port, are subjected to a careful inspection by an engineer surveyor of the Board of Trade, who can require the boiler to be tested in the usual way to twice the working pressure; and if he think fit, he can, as the result of such an examination, place the option before the shipowner of either lowering the working pressure or renewing the boiler. Armed with such powers, the Government surveyor is also responsible for any explosion which may directly occur through wear and tear. When an explosion takes place on a passenger railway, one of the Board of Trade inspectors of railways examines the fragments, and reports upon the accident to the Government board, who communicate it to the railway board. The reports are then printed, in order to be presented to Parliament, and this is the extent to which the British Government can interfere in these cases. As with other railway accidents, however, the Board of Trade inspector is examined as a witness in any action for damages against the railway company. All other boilers in the United Kingdom are worked without any Government or municipal interference whatsoever. Within late years, however, private companies (the first of which was organised by Mr. Fairbairn, of Manchester) have been formed for the prevention of boiler explosions. In return for a small annual fee, or for a small annual insurance premium, the boilers of any subscriber or insurer are periodically inspected, and, if required, tested by skilled engineers. There can be no doubt that these companies have already prevented a great amount of loss and disaster.

It may thus be said that there are three distinct plans for the general management of steam boilers:—1. There is the continental plan; 2. the free English and American mode; 3. what may be termed the Manchester system. The continental mode consists in a strict supervision, sometimes ruled by formulæ, of the original construction, and there its action may be said, for the most part, to end. It does not, and cannot, without periodical inspections, take into account the effects of wear and tear. It may even be doubted whether the old French law, for instance, did not do more harm than good as regards construction. The official formula, according to which were calculated the thicknesses of the plates, founded as it was on the assumptions that a cylindrical boiler formed an exact circle, and that a plate, however thick, conducted the same amount of heat to the water, was obviously incorrect. What may be termed the ordinary English and American plan throws the onus of proof of the negligence of the owner on those damaged by an explosion. This system is subject, besides other difficulties, to all the objections that exist against the trial of scientific questions by a jury not composed of experts, and unaided by scientific witnesses. The continual occurrence of explosions in those cities and states of America in which boilers are used without any supervision by the authorities, and their undue occurrence in England with boilers that are not subjected to systematic inspection, sufficiently prove that steam boilers cannot be worked at hap-hazard. On the other hand, the system of organised inspection by the English boiler companies, and the similar system according to which the passenger vessels are inspected by Government officers, have given universal satisfaction. A proper estimate of the value of the Manchester and Board of Trade system, compared with the continental and with the *laisser faire* plans, could only be well based on numerous statistics. Unfortunately, such do not appear to have been formed. It is stated,* however, that in an average of 277 boilers, there were two explosions in the French department of the Haut-Rhin within ten years; and from 1856 to 1861, or within five years, there were only two explosions in an average of 1371 boilers under the care of the Manchester Association. About four explosions occur annually amongst the 6500 locomotives of the United Kingdom; three have already taken place this year. In an average of 600 passenger vessels inspected under the Steam Shipping Acts, only three explosions occurred since 1846-7 in Great Britain—viz., one at Lowestoft, in the Tonning; another at Southampton, in the Parana; and a third at Dublin. These last results speak very highly for the care and abilities of the Engineer Surveyors of the Marine Department; and the Continental system is thus clearly inferior to that adopted by the Board of Trade. What is evidently wanted is that the system of skilled periodical inspection should spread over the kingdom. To a certain extent this is taking place, but this progress is slow, and needs some stimulus, while it is doubtful whether, in out-of-the-way districts, the mere expense of inspection is not a great bar. What seems to be needed is that in the event of a fatal explosion the coroner of the district should be enabled to write to the Home Office for scientific assistance in arriving at the originating cause. The Secretary of State might then call upon any competent engineer for a report on the matter, when he could be examined as a witness before the jury. The mere knowledge that any explosion would be strictly investigated by an expert, might in many cases be sufficient to counterbalance the too prevalent tendency to prefer risk to expense.

The Hydraulic Test.

Although, as we have seen, the application of a known amount of hydraulic pressure is in such general use for the determination of the strength of a boiler, there are, nevertheless, few points in engineering about the real value of which there is so much dispute. Everybody seems to have a different opinion on the matter. Some say that the hydraulic test is the only means of determining the strength of the boiler; others, that it is a very injurious and useless measure. As to its amount, some recommend one and a half, many twice, some thrice, and a few even four times, the working pressure. While numerous engineers advise its application to old boilers, others have strong objections to its use in this way. Whether the force-pump be really the best apparatus for its application, is, with other questions, also placed in doubt. The truth is that, while on the one hand, like other tests, it may be abused and wrongly applied, on the other its value may also be exaggerated.

The best practical proof of its necessity for new boilers is afforded by the fact that explosions have occurred the first time steam has been got up; such as that at the Atlas Works, Manchester, in 1858. Unless every plate be separately tested up to proof load, it is impossible to be certain whether one of them is

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* Reichs-Gesets-Blatt fuer das Kaiserthum Oesterreich, 1854; p. 229.
† Ministère des Travaux Publics, Machines à Vapeur.—Règlement. Donné à Laeken le 21 Avril, 1864.
‡ Grossherzoglich Mecklenburg-Strelitser Offizieller Anzeiger, No. 11, 1863.
§ Gesetzliche Verordnungen die Anlegung von Dampkesseln betrefend. Dresden, Meinhold und Soehne, 1866.
|| Regierungs-Blatt fuer das Kœnigreich Bayern, 22 Februar, 1865.
¶ Gesets-sammlung fuer das Kœnigreich Hannover, 1863.
** Merchant Shipping Act, 27th June, 1854, Nos. 289 and 298.

* Bulletin de la Société Industrielle de Mulhouse, 1861, p. 525.

not defective. This function is clearly much better performed by the hydraulic test. Then as to its application to old boilers, much can be learnt during internal examination, but it is not always possible to tell the remaining thickness of the plates by this means, nor their deterioration through the heat. It is often said that a successful resistance to the hydraulic test is no proof that the boiler might not have been burst by a few pounds more, and that it may so suffer as to perhaps afterwards burst with a less pressure of steam. But this is no more true than it is true of a girder, for instance, which has withstood without permanent deflection its proof load. In every case it is necessary that its effects on the boiler should be exactly ascertained. In fact the real test consists in this examination, and the proof pressure is only a means to this end. The boiler should, if possible, be subjected to a careful internal and external examination. With locomotives this can only be accomplished by taking out the tubes; with ordinary land boilers it can only be done by removing the brickwork. In fact, it may be said that a steam boiler is never absolutely safe which cannot be easily examined; more especially from the inside. But by gauging the flue tubes, the combustion chambers, the flat surfaces, and even the barrels, it may be ascertained very nearly whether the limits of elasticity of the material have been exceeded; whether therefore the pressure has additionally injured a boiler which was near rupture already. It is often very plausibly observed that there is great danger in testing a boiler which cannot be examined internally, to double, or even to only one and a half the working pressure. It is said that the test may strain the boiler without its showing any outward indication. It is certainly just possible that such a case might happen. A locomotive boiler, which had been tested with 196 lb. pressure, the water being at 162° F., in September 1860, but had not been examined internally, burst on the 1st of April, 1861,* under only 120 lb. of steam. The boiler gave way at the smoke-box ring of the barrel, and, as usual, from a furrow or crack running close to and parallel with the inside overlap of the longitudinal joint. It is difficult to believe that if this ring, as well as the others, had been gauged after stripping the lagging from the outside, as is done by the engineers of the Manchester Boiler Association, it would not have shown a permanent increase of diameter, or some bulging under the extra pressure. If, in addition to a neglect of careful measurements before and after the application of the pressure, this test is carried very high, then the whole operation may undoubtedly be a cause of that which it is intended to prevent. According to the Prussian law, every new locomotive boiler had to be re-tested to double the working pressure after running 8000 Prussian miles, and afterwards for each 5400 miles. These measures, while they did not entirely prevent explosions, greatly injured the boilers by straining the staybolts, and by the resulting excessive caulking required to make the joints tight. On the other hand, the absolute security afforded by drawing the tubes can, under the present mode of construction, be only obtained at the expense of, perhaps, 300 tubes, costing from 25*s*. to 27*s*. each, besides some injury to the tube plates.

Whatever may be said against the hydraulic test, the best argument in its favour is its very general adoption. New government boilers in the United States must be tried to a pressure two-thirds greater than the working pressure; the same measure being carried out with the 3000 boilers in the city of New York. Mr Anderson, C.E., of Woolwich,† directs his subordinates to use a test of at least double the working pressure for the boilers in the royal gun factories. Mr. Muntz, of Birmingham, has publicly stated that he has for years adopted an annual hydraulic test, "considering it a duty he owes to his workmen." The Eastern Counties, the South Eastern, the Lancashire and Yorkshire, the Caledonian, the North British, the Edinburgh and Glasgow, and the London and South Western Railway Companies, employ the hydraulic test for both new and old boilers, using generally double the working pressure. The London and North Western are stated to have used it for only new boilers—at any rate, until recently. The Great Northern and the Great Western Railway Companies do not use it, and it is accordingly on these lines that the greater number of explosions take place. Practical experience thus proves that, though there is just a chance of the test failing to detect a weak boiler when it cannot be examined internally, the danger is greater in not using the hydraulic test at all. Mr. Beattie, of the London and South Western, strips the lagging every two years, and applies a pressure of 190 lb., the working pressure being 125 lb. Mr. Fletcher, of the Manchester Boiler Association, employs double the intended working pressure for new, and from 1½ to 1¾ the working pressure with old boilers. The most commonly used test is thus double the working pressure for old boilers, with a diminution according to circumstances as they get old.

An objectionable plan in measuring the pressure applied, and for several reasons one likely to lead into error, is estimating it from the load on the safety-valve lever. A metallic gauge should be used, and very neat pocket instruments of the kind are sold in Paris. In frosty weather the rivet-heads are liable to be snapped if the metal be not somewhat warmed by using hot water. The hydraulic ram kind of action on the sides is also much less likely to occur if a rather narrow force-pipe be used for the pump.

There can be no doubt that it would be a valuable thing to be able to employ some means of measuring the permanent and the temporary extension of volume, if any, produced by the hydraulic test. It is probable that a boiler, as it gets old, and takes a permanent set under the pressure, also increases in volume; so that it doubtless holds a few gallons more than it did when new. An ingenious plan for measuring the increase of volume is recommended in the Bavarian regulation. After the boiler is filled, the amount of water forced in is measured, by pumping it from a vessel marked with divisions. When the pressure is removed the boiler contracts more or less, forcing out at least a portion of the water; the amount remaining is supposed to give the dilatation of volume of the boiler. The difficulty in the use of this plan would probably consist in the presence of air in the water itself, and any which might chance to remain in the boiler. That in the water might be greatly diminished, or at any rate brought down to a constant amount, by boiling; but there would be no precise security against any air in the boiler, and as the weight of the air absorbed by water, according to a well-known law, is in proportion to the pressure, it would be taken up by the water, thus falsifying the indications when the pressure was removed. On the other hand, a high temperature of the water would form an impediment to this absorption. The experiment is certainly worth trying. It might be very valuable with tubular boilers inaccessible from the inside, as any permanent set or deflection ought to be indicated by little or no water being compressed out by the contraction of the boiler on the removal of the pressure. As long ago as 1844, Mr. Jobard, of Brussels, in order to obviate the supposed injurious effects of the hydraulic blow of the water on the plates, proposed to fill the boiler with water, first loading the safety valves, and to then dilate the water, and consequently the boiler, by means of heat applied to the outside.* More recently, Dr. Joule, of Manchester, has used the same plan himself, proposing it for general adoption.† In addition to the loaded safety valve, he used a metallic pressure gauge, to be constantly observed, and if the pressure arising from the expansion of the water goes on increasing continuously without sudden decrease or stoppage until the testing pressure is obtained, it may be inferred that the boiler has sustained it without having suffered strain. Another plan, also founded upon the same principle of the irregularities of extension of metals when the limit of elasticity is exceeded, has lately been proposed.‡ This consists in bringing an ordinary steam-engine indicator in communication with the pump plunger as if it were a steam-engine piston-rod. The ordinates of the pencil diagram would thus give the pressure in the boiler, while the respective abscissæ would give the quantity of water pumped in at each stroke. As long as the limit of elasticity was not exceeded there would be a horizontal line, while a curved line would appear as soon as the sides began to take a permanent deflection. There seems to be a sort of contradiction in depending for results like these upon such irregular appearances as the extensions beyond the elastic limit. But all these proposals are undoubtedly worth trial in practice. Dr. Joule's plan has the merit of affecting the plates by both heat and pressure—thus bringing them under every-day conditions.

† Board of Trade Report, 1861. Part 4.
‡ "Instructions to be Observed in the Management of Steam Boilers in the Royal Gun Factories."

* "Technologiste," 1844. p. 185.
† "On a Method of Testing the Strength of Boilers." Journal of the Manchester Philosophical Society, 1862, p. 97.
‡ Polytechnisches Centralblatt, p. 1337, 18 October, 1864.

METROPOLITAN IMPROVEMENTS.*

By W. Penfold.

It has of late years been the fashion to sneer at the attempts made in this country to carry out such improvements as have become necessary from time to time in our metropolis, and to draw unfavourable comparisons between what is done here and what is done on the Continent under similar circumstances, and especially with regard to the magnificent works which have been carried out in the capital and provincial towns of France under the auspices of the present Emperor.

Now, although we do not enjoy the advantages of a paternal government, to guide and preserve us in the right path, like our neighbours across the Channel, and our civil improvements, taken one by one, will perhaps hardly bear a comparison with theirs, either in grandeur of conception, or in the rapidity and spirit with which they are carried out; still, a glance at the extent and conditions of our metropolis some sixty years ago, will soon convince us that a very large aggregate amount of work has been done—some of it, no doubt, wretchedly conceived and badly executed—but which on the whole will bear a very favourable comparison with what has been accomplished in the same time in any part of the Continent.

Let us take a map of London at the time we are speaking of. There is one entitled 'The Stranger's Guide to London and Westminster, exhibiting all the latest improvements up to the present time,' published in 1806. We shall find that, practically, the City was bounded on the north by the New-road,—Gower-street ended in a market garden,—and it was a pleasant walk by Bagnigge-wells, the Merlin's Cave, and the New River reservoirs, to the Angel at Islington. Parties to Primrose-hill could stroll through Marylebone-park Farm (belonging to the Crown), and stop to refresh themselves at the Jew's Harp, if they desired anything more potent than the curds-and-whey they would obtain at the adjacent farm-house. The inhabitants of Westminster might walk across Tothill-fields to the river, and be ferried over to Vauxhall-gardens; or if they wished a quieter walk, might turn to the right, through the Five-fields belonging to the Earl Grosvenor, and passing the large reservoirs of the Chelsea Water-works, go by the Royal Hospital on to Chelsea-common. Westminster, Blackfriars, and London were the only bridges below Battersea. The access from London-bridge to the Royal Exchange was by way of the narrow Fish-street-hill and Lombard-street; while we can only hope that very few people were obliged to attempt the difficult passage from the Bank to Finsbury-square, up Coleman-street and Little Moorfields. Regent-street did not exist; and the Royal Mews, at Charing-cross, however convenient it may have been for the Prince Regent at Carlton House (close by), must have seriously impeded the traffic at the junction of the leading thoroughfares of the Strand, Whitehall, and Charing-cross. The possibility rather than the probability of being whirled through the air at the pace of 10 or 12 miles an hour by steam on a railway was only then beginning to haunt the dreams of a few enthusiasts; and Londoners journeyed 7 or 8 miles out of town to be astonished at the marvel of a long string of coal trucks drawn by two or three horses along the Surrey Iron Railway, just then completed, to connect the river Thames at Wandsworth with the inland towns of Mitcham and Croydon.

Until within the last ten or twelve years, however, it has been tolerably easy for any one whose attention was directed to these matters by business or inclination, to keep pretty well informed on the subject; but since then, such rapid and important changes have taken place, and others of still more consequence are in contemplation, that the difficulty of obtaining, or rather of retaining, the information has much increased, while the necessity for its acquisition, in a professional point of view, is daily becoming more obvious and pressing. It is now a matter of every-day occurrence for an architect to be called on to advise on the eligibility of a building estate, or as to the site of a new building and the effect which the opening up of some new street or railway, or the contemplated diversion of a line of traffic, may have on the business or the objects for which it is proposed to be erected; besides the many other incidents of an architect's ordinary practice, in which the knowledge of the present or prospective value of property plays so important a part. Looking on the subject from this professional point of view, I have thought it might be of some advantage if I were to lay before the members of the Association a brief outline of some of the most important works which have been executed during the present century, and include in my survey some others which are already in progress or on the eve of being commenced. With the object I have just indicated in view, I propose to confine myself chiefly to a consideration of those undertakings which have been set on foot for the purpose of affording new or increased facility of intercommunication between different parts of the metropolis; the principal points we shall have to notice, therefore, will be bridges, streets, and railways.

Now, any one who has not thought much on the subject, as he walks down Regent-street, or along Cannon-street, and sees the line of splendid shops or ranges of lofty warehouses, knows very well that if he wishes to buy or rent premises, either in one street or the other, a price will be asked amounting almost to a handsome yearly income for a man of moderate expectations; and the idea may occur to him, what a fine speculation it must be to get an Act of Parliament, and open up a new street like this! But he would think it strange, when he came to inquire more closely, and was told that the actual net loss on carrying out a new street is equal to one-half or two-thirds of the money expended, and that that proportion of his capital would be utterly sunk and lost. Cannon-street, which was only half a street, has, I believe, turned out the least loss of any recently executed, and it entailed a loss of 40 per cent. The leases of houses in Regent-street might have been bought after they were built, at prices equal now only to the rents which they realise per annum. This arises from several causes, the principal being the fact that a new street is generally made through a densely-populated locality; and the area occupied by so many small houses, all of which have to be paid for by heavy compensation, is thrown into the improved width of roadway, which does not return a direct equivalent profit in the increased value of the frontages thereto. Again, it is a long time before a new street takes with the public or the shopkeepers. The slow progress of New Oxford-street towards respectability is a case in point; and at the present time it has hardly got into the position it ought to occupy as a leading thoroughfare. It is obvious therefore, that the ways and means for accomplishing any of these undertakings are of the utmost importance; and to this subject we will devote a few preliminary observations, as the sources from whence such funds are derived must of necessity exercise an important influence, both on the character of the projects themselves, and on the rapidity and manner in which they are carried out.

First, then, it is well known, I have no doubt to all, that the revenue of the estates belonging to the Crown is made over to the executive Government in return for what is called the Civil List, or parliamentary allowance to the sovereign. These estates are vested in commissioners during the life of the reigning sovereign, the reversionary interest of the estates being reserved for his successor. These estates themselves are therefore kept intact, the commissioners dealing with the revenue as may be deemed advisable in the interest of the State. It is with a portion of this revenue, aided by grants and loans from the Consolidated Fund, that many of the improvements at the West-end, where the Crown has valuable estates, has been effected; the two-fold object of accommodation to the public and increase of value to the reversion of the estates being for the most part kept in view.

Next, perhaps, we should mention the Corporation of the City of London, who have a large revenue derivable from property in their possession, and a great proportion of this is annually devoted to improvements from which no direct profit accrues to them. They have also been intrusted, from time to time, with the administration of large funds which have been raised with the sanction of the legislature for making new streets and other works, such as London Bridge and approaches, the Royal Exchange approaches, and others of equal importance. The chief source of the revenue which they have thus administered is the well-known Coal Tax. This duty consists of 1*s.* 3*d.* per ton on all coals brought within a radius of about 20 miles of the City, and was originally granted in the time of William and Mary, for the relief of the orphans and other creditors of the city of London, and has been continued from time to time by various Acts of Parliament which point out the specific purposes to which it is to be applied. Now the coal tax produces £240,000, and in 1836 it was about half that amount. The commissioners of sewers, also, of the City of London have a

* Read before the Architectural Association.

separate fund raised by taxation, out of which they are constantly, bit by bit, improving existing streets and setting back projecting houses whenever an eligible opportunity presents itself for so doing. There are also the local boards, and the Metropolitan Board, who have certain powers of taxation, and now generally administer the funds derived from public sources for most of the important civic undertakings. A further source of revenue, in years now gone by, was the profit derived from the State lotteries; and with it Westminster-bridge and the improvements at Snow-hill were partly executed. The profits were between £300,000 and £400,000 per annum. This was rather too good a sum to lose on the score of morality, and the committee, if they did not actually recommend, very strongly suggested that there would be no harm in raising by way of lottery, or, as some of the witnesses put it, of availing themselves of voluntary taxation, a sum of about £120,000 per annum, to be appropriated to improvements from which the public themselves would derive the benefit.

Bridges.—Facilities for crossing the river are, perhaps, the most important to a city like London. Bridges, therefore, seem to claim our first attention; and first among these comes London-bridge. We are all familiar with the aspect of old London-bridge, as it appears in old prints and engravings. There is a very good view of it in the Vernon Gallery, with its houses, gateway, mills, chapels, and narrow arches. The Great Fire of London, in 1666, destroyed most of the buildings, and damaged the bridge; they were, however, restored in a great measure, and so remained till about 1754; when an act was obtained for clearing off the houses, throwing two of the arches into one, and otherwise improving the bridge. This was done from designs by Sir Robert Taylor and Mr. Dance, and as it stood after this the bridge consisted of nineteen arches of various spans, the water-way at low-water being only about 231 feet, while the space occupied by the piers and starlings was 700 feet. This, of course, was a serious obstruction to the traffic; and at length, after having been duly sat upon and reported upon by various committees, an Act of Parliament was obtained in the year 1823 for the erection of a new bridge. This was commenced in 1824 from the designs of Mr. Rennie, and opened on the first of August, 1831. The bridge is built of stone, and now consists of five arches, with a water-way of 690 feet, and a space occupied by piers of 92 feet only. The cost of the bridge was about £426,000, which was raised principally from the Bridge House Estates, belonging to the corporation.

The Act of Parliament for the construction of Blackfriars-bridge, which was originally called the Pitt-bridge, was obtained in 1756, under powers given to the corporation of the City of London, who were empowered to raise a sum of £30,000 per annum by tolls, to pay off part of the expense. Out of a large number of designs, among which were some by Smeaton, Chambers, Dance, and others, that by Mr. R. Mylne was eventually selected. It was commenced in 1760, and completely opened in 1770. It was built of stone, and consisted of nine arches, leaving a water-way of 788 feet. The cost of the bridge and approaches was about £265,000; of this about £166,000 may be put to the expense of the bridge itself. However, from some inherent defect in the foundations, the arches sank; and between the years 1832 and 1843, £105,000 were spent in repairs, and since that time it has been a source of constant expense to the corporation. The parapets were taken off and replaced by wood; and within the last year or two the corporation obtained a number of designs, and the new bridge, which is to be somewhat similar to that of Westminster, is now being erected under the superintendence of Mr. Joseph Cubitt.

Westminster-bridge was commenced in 1739, from the designs by Labelye, and finished in 1750: about £300,000 were expended. It consisted of fifteen arches, leaving a water-way of 820 feet. This bridge also, like Blackfriars, seems to have been a constant source of annoyance and expense. Even during its building, in 1747, one of the arches failed, and had to be made good at a large expense. The whole structure became so bad that, as we all know, it was taken down and replaced by the present structure from the designs of Mr. Page, which was commenced about 1855. There are seven main arches and two or three smaller ones. The bridge is nearly twice as wide as the old bridge, being 85 feet against 44 feet of the old. The bridge was erected in halves, the old remaining while half of the new was building; this delayed the completion. The cost was about £316,000, besides the approaches.

In 1809 the Strand Bridge Company was incorporated, and they were empowered to raise £500,000 in shares, and a further sum of £300,000 on mortgage. Further powers were obtained in 1816, and the name was changed to Waterloo. The bridge was commenced in 1811, from the designs of Mr. John Rennie, and opened in 1817. It consists of nine arches, with a water-way of 1080 feet. The original estimate for the bridge alone was £680,000, and it deserves to be recorded to the credit of Mr. Rennie, in a work of such magnitude and so much uncertainty, that the estimate was not exceeded by more than £5000. The total cost of bridge and approaches, with expenses, was £1,030,852, which was raised by shares, annuities, and bonds. The company met with great opposition from the City, and Mr. Mylne, their engineer, stated before the committee of the House of Commons that it would be impossible to build a bridge on the site; and if built, it could not stand. It, however, has survived to the present time, and seems likely to last still longer, while Mr. Mylne's bridge is fast disappearing from the face of the earth. Whatever advantage this bridge may have been to the public, the shareholders have not derived much profit, and although, since the opening of Waterloo Station, the traffic has increased, some years ago the £100 shares might have been obtained for about £3; and the clerk to the company, in evidence before a committee in 1836, on a question of opening the bridge free of toll, said that the then market value of the whole property—shares, annuities, and bonds—was £303,841, or about £700,000 less than the cost.

Southwark-bridge, an iron bridge, was also designed by Mr. Rennie. It has three arches, with a water-way of 660 feet. It was commenced in 1814, and opened in 1819. The expenditure of capital for the bridge and approaches, and other expenses, was £666,486, of this £186,000 were paid for purchase of property, £278,000 for masonry to bridge, £143,000 for iron-work to bridge and approaches, and £60,000 for miscellaneous charges. About £150,000 were raised by preference shares at 5 per cent., and the holders of these are the only proprietors who have received any dividend, and these only at the rate of 2 or 3 per cent. The £100 shares might have been bought at £2 or £3.

Vauxhall-bridge is also a cast-iron bridge; it was designed by Mr. James Walker, and carried out by him, though Mr. Rennie and Sir James Bentham seem to have had some hand in it. It was commenced in 1811 and opened in 1816. It has nine arches, and the cost was about £300,000.

Lambeth-bridge was erected by a private company. It is on the suspension principle, being of wire cable. The bridge has three spans, each of 280 feet; the piers are cast-iron cylinders the same as Hungerford. There is a carriage-way and footpaths, the total width being 32 feet. The works cost about £28,000, the whole cost, for land, &c., being £40,000.

Chelsea-bridge, which connects Battersea-park with Pimlico and Chelsea, is a suspension-bridge. The width of the river at this point is 737 feet, which is crossed by three spans, the central one being 352 feet between the piers. The roadway is 32 feet in width; the footways overhang, and are each 7 ft. 6 in. wide. The four towers which support the chains are of iron, except about 18 feet at the top, which are of copper partly gilt. The bridge and the embankment in connexion are from the designs of Mr. Thomas Page.

Streets.—The first perhaps that claims our attention is that of Regent-street, and the works connected with it. The immediate cause of its being undertaken was the desire of the Commissioners of Woods and Forests to improve the Marylebone-park Farm, belonging to the Crown, and the lease of which had just expired; and also (through the influence of the Prince Regent) to form a good means of communication from Carlton House to this estate, where it was proposed that a residence for him should be erected. There was a competition, with a premium of £1000, for laying out the proposed park and forming the necessary communications, but the result does not seem to have been satisfactory; and eventually a plan, which was a combination of the designs of Messrs. Leverton and Chawner and Mr. Nash, was adopted. This was about 1813, and in a few years the Regent's-park, as we now see it, was fenced in and planted and the terraces built. The net cost of laying out the Regent's-park was about £20,000. This was paid out of the revenue of the Crown estates. Regent-street was opened some time in the year 1819. The total cost of forming the street, for compensations and other expenses, seems to have been about £1,406,000, and the expense of the sewer £60,800 besides. Of this amount £515,000 were paid out of Crown revenues, and £800,000 out of the Consolidated Fund.

As the improvements in Regent-street drew near their completion, those in the neighbourhood of Charing-cross were commenced, and comprised the extension of Pall-mall into the Strand, by cutting off a part of the churchyard of St. Martin's, clearing away the King's-mews, and the formation of Trafalgar-square, and widening the Strand and St. Martin's-lane at their junction with the extension of Pall-mall. Up to the year 1835, these improvements had cost about £1,500,000, principally defrayed out of the revenues of the Crown lands, and carried out under the superintendence of Mr. Nash.

In the meantime considerable improvements had been going on in the City. London-bridge I have already alluded to; and, in connexion therewith, the street from the Mansion-house to the bridge, now called King William-street, was carried out, as also the continuation of that thoroughfare to Finsbury and the New-road by way of the present Princes-street and Moorgate-street. These works were carried out under the superintendence of Sir Robert Smirke, and Mr. Montague, the City Surveyor. King William-street cost about £212,000; Moorgate-street about £156,000; the approaches on the Surrey side about £300,000; and other matters in connexion made the total cost about one million, and this burden was laid on the coal tax. St. Thomas's Hospital, the burning of the Royal Exchange also, and its re-erection, necessitated great improvements in the neighbourhood of the Bank and the Mansion-house; and these were also paid for out of the coal-tax fund. Some new openings in connexion with Waterloo-bridge were also carried out at this time.

In 1836 a committee of the House of Commons was appointed, of which Alderman Wood was the chairman, to inquire into a variety of schemes connected with London and Westminster, among which were the improvement of Skinner-street and Snow-hill by a viaduct; a new street from St. Paul's to Blackfriars-bridge; from Farringdon-street to Clerkenwell; from the Post Office to the Bank; Westminster Abbey to Pimlico; Finsbury-square to Whitechapel Church; St. George's Church to Blackfriars-bridge and Waterloo-bridge; and opening Waterloo-bridge and Southwark-bridge free. Mr. Donaldson, Mr. Montague, Mr. Cottingham, and others, gave evidence, and submitted plans. In 1838, the committee were again engaged on the same subject, and they recommended Cranbourne-street, Endell-street, New Oxford-street, and Spitalfields, for some of which plans had been prepared by Mr. Nash.

In 1844 and 1845, Cranbourne-street, New Oxford-street, and Spitalfields-street were opened at an expense of about £841,000. These were carried out under the superintendence of Mr. Pennethorne.

The improvements in Westminster, and notably Victoria-street, were entrusted to commissioners, who were incorporated by the Westminster Improvement Act, 1845. This, however, did not work very satisfactorily, and an Act was required nearly every following year up to 1852 and 1853, giving powers to raise various sums of money, amounting to something like 250,000. The commissioners also obtained powers to lend money to builders, which they did to the amount of about £400,000. They also issued a large number of bonds without sufficient security: these got in the market, and became depreciated in value; the creditors interfered, and there was the usual crop of Chancery suits. And in the years 1859 and 1860, Acts were obtained for reconstructing the commission on a new basis, and making arrangements for paying off the creditors: Mr. Tite having been persuaded to take a leading part in the new constitution.

Cannon-street had also been opened in the mean time, at an expense of about £500,000, paid chiefly by the Corporation of the City.

The Act for the new street in Southwark was obtained in 1857. The works were commenced in 1861, and the whole of the street was thrown open to the public on the 1st of January, 1864. The street is about two-thirds of a mile long, and the estimated cost was £519,424, including about £9000 for sewer. Instead of the sewer a subway was carried out, at an expense of about £25,000, including which the total cost of the street has been £557,051, a result creditable to Mr. Marrable, who carried it out; and it is anticipated that of this amount about £267,000 will be recovered by sale of land, &c.

Almost every engineer and architect who has taken any leading part in such matters, from the days of Sir C. Wren downwards, has been pressing on the notice of the authorities the necessity of embanking the Thames. Almost every committee has reported on the subject and earnestly recommended its adoption. John Martin, the painter, made great efforts, extending over twenty-five years, to get a design he had made carried into effect. In 1842 a commission, with the late Duke of Newcastle for chairman, was appointed, and many designs were laid before them; but nothing was done except here and there in connexion with other works, and by private individuals, according to a line laid down by Messrs. Walker & Burgess; and it was not till 1861, after the Metropolitan Board of Works had been empowered to carry out the main drainage, and the inhabitants of the Strand, along which the low-level sewer was to be carried, became alarmed at the prospect of being enclosed in a hoarding for a year or two, that any serious steps were taken to carry out this long contemplated scheme. In this year another commission was appointed, who took evidence and received a large number of designs, one by Mr. Shields being the basis of that proposed to be carried out. The commission recommended the embankment, and a new street from Blackfriars to the Mansion-house. An Act was then passed, providing funds for the embankment, by continuing the Coal and Wine Duties till 1872. The necessary plans were then prepared, and, after much opposition from the Duke of Buccleuch and others on the question of carriage traffic, the Thames Embankment Act was passed in 1862. This Act authorises the construction of an embankment, with a roadway of 100 feet wide, and the necessary junctions of existing streets therewith. The width of the embankment varies from 450 feet, near Buckingham-street, to 130 feet by Somerset House. The works were commenced at the end of 1863, and two contracts are let; one, from Westminster to Waterloo, by Mr. Furness, at £520,000; and the other, from Waterloo to near the Temple, by Messrs. Ritson, at 229,000: this includes the embankment, sewer and subway. The Act for the Thames Embankment did not include the powers for the new street to the Mansion-house, the Act for which was obtained in 1863 by the Metropolitan Board, after some sparring with the City authorities, who wished to have the administration of the funds, and the honour of carrying out the work.

The railway will pass up the middle of this street, which is not yet commenced. The street will have a subway. In revenge for slight put upon them in giving to the Metropolitan Board the works of the new street within their boundary, the Corporation applied for and obtained, last session, the Act for the Holborn Valley Improvement.

SILT TRAPS ON THE DEHRA DOON CANALS, INDIA.*

By R. E. Forrest, *late Superintendent, Doon Canals.*

The first silt traps built in the Doon were of the form shown in Fig 4. The mode of action, and the application of the principle of subsidence are at once evident. The water is diverted from its straight course into the first chamber of the reservoir, pours through a slit in the top of the dividing wall into the next chamber, and from there returns again into the canal. The silt settles down into the deep and comparatively still water of the chambers. By giving the beds of the chambers a slope towards the end wall, and having openings at its foot, the silt was got rid of at once solely by the action of the canal water.

These silt traps were built on the Kutta Puthur canal and the Rajpore water-course. Similar errors of construction attached to both of them, which caused them to be of little service. But there was an error of position in the latter which soon led to its total abandonment. The Kutta Puthur canal silt trap opened on to the Jumna river, and its silt evacuations were thus speedily got rid of. But that on the Rajpore canal was connected with the natural stream by means of a long and tortuous channel. The consequence was that heavy silt deposits took place in this channel. A mound of silt was formed at the foot of the silt trap, advanced on it year by year, and finally rested against the end wall to its top, and the silt trap had to be abandoned. It had in fact got buried in silt. It is a point never to be lost sight of that a silt trap ought to open immediately on to some natural stream. It ought never to be attempted to carry away the silt by means of flushes from the silt trap itself and along an artificial channel. If possible, the high water of the natural stream ought always to come up to the foot of the silt trap wall.

The errors of construction in these first silt traps were—

* Continued from page 188.

1. That the dimensions of the canal were carried through each part of the silt trap, the width of the chambers and of the opening in the dividing wall being made the same as the width of the canal. The consequence was that the water flowed through the trap with a considerable velocity, and thus carried on a great quantity of silt. 2. That the gates for the openings at the ends of the foot wall were large and clumsy. There was a great loss of water through them; and being 4 feet square, they were difficult to lift, more especially when the silt deposit quite covered them; it was then like trying to pull up a pile out of sand.

The next silt trap built was that on the Kalunga canal, in which these defects were remedied. Here (Fig. 5) a double set of chambers was employed. Greater stillness was obtained by having these additional reservoirs, and also by placing the openings in the separating walls at alternate ends, by which means the water had three turns in its course through the trap. And with a double set of chambers, one set could be kept in action while the other was being cleaned out. Two different kinds of gate were employed. For the openings in one set of chambers they consisted merely of small rectangular plates of iron, 1½ feet deep by 1 foot broad, which rested against the sides of square beams previously let into the wall. They were held against the opening, and moved under two thin strips of sheet iron attached to the wooden beams, and which covered their edges for 1½ inches (see Fig. 6.) These plates were inside the reservoirs, and the pressure of the water made them almost perfectly water-tight. They were moved up and down by means of a long iron rod attached to them, and which reached to the top of the end wall. The upper foot and a half of its length was cut into a screw. As the shutters could not descend by their own weight owing to the spring-like pressure on them of the strips of iron, it was necessary that the rods should push them down as well as pull them up, in fact that the screw should act both ways. This was effected by the arrangement shown in Fig. 7. The doubled handled lever, used for turning the fixed nut, has an octagonal socket in the middle of its length, which fits over the octagonal nut. When the lever is worked to the left, the gate is pushed down; when to the right, the gate is lifted up.

This is undoubtedly the best form of gate that can be adopted. There is no leakage through it, and the screw affords the most perfect mechanical agent for working it. But its very perfection was one objection to it; it was too good for the locality. If anything happened to the screws there was no means of having it remedied within a distance of fifty or sixty miles. Again, while admirably adapted for a regulating gate it could not be used as a flood-gate. And this last was absolutely needed, for when the chambers rapidly filled with up silt, there was danger of the water flowing over the walls of the silt-trap. Another form of gate was therefore employed in the other two chambers. The principle of their construction is extremely simple, and they can be made up by any village carpenter. Their mode of action can be easily understood from the diagrams. The gates open outwards, so that the force which opens them is the pressure of the water. The bar which keeps down the gates (Fig. 8) runs into two openings made in the side beams *cd*, *ef*, which project a good deal beyond the surface of the gate, and its ends fix into two sockets, one of which runs upwards and the other downwards. The gate, as shown in Fig. 8, is closed. If the end A be struck from above it will descend, while the end C will ascend, till both ends come opposite the openings *m*, *n*, in the side posts, through which they fly out, and the gate flies open from the pressure of the water within. It will be observed that the pivot *p*, on which the bar turns, is placed so as to give the advantage of the leverage to the descending stroke. It will be observed also that the end of the bar being octagonal, it is only the pressure on the length of side of the octagon which has to be overcome. Hence the gate is thrown open with the greatest facility. One man can strike open three gates, with a pressure of 14 feet in depth of water on them, with the greatest ease.

The bar may be struck from the top of the end wall with a pole, or from the tops of the small projections, *mn*, *op*, (Fig. 5.) built on each side of the gates. I do not know if this form of gate has been employed elsewhere. It seems to me that it might with great advantage be employed in the flood-gates for dams and weirs. The fact of the gates swinging from above would militate against its employment in the centre of a dam or weir across a river subject to heavy floods. But from the extreme rapidity with which they can be struck open, they would be of great service for side sluices meant to relieve the first rush of water in floods. The simplicity and cheapness of their construction, no iron-work at all being employed in them, render them suitable for the wild and uninhabited districts in which the heads of canals are generally situated.*

While the silt-traps first built were of little service, or had to be abandoned altogether, the Kalunga Canal silt-trap has done good service for the past six years. The use of the double chambers becomes at once apparent on examining the quality of the deposits in each chamber. In the first two is chiefly coarse heavy gravel; in the third, coarse silt; in the fourth, fine silt. The last was never deposited in the old silt-traps, but was carried on into the canal.

There were still, however, many faults in this form of silt trap. The dimensions of the canal being still carried through the trap, the velocity was very great; perfect stillness had not been obtained. It is obviously a mistake that the last opening out of the trap should be of the same size as the first opening into it. It was an error in engineering to have so great a length of fall at the end wall, standing *en l'air*, while exposed to the full pressure of the water. From these considerations it became evident that an improved form of silt trap ought to have—1. The opening for the exit of the water as wide as possible. 2. The openings for communication at the foot of the dividing walls of the chambers. 3. The end wall to be as short as possible. These principles were accordingly carried out in the silt trap last built, viz., that on the Rajpore canal. It will be observed that the water passes out of the trap (Fig. 9) over a long weir. The length of this was calculated so that it should have only 3 inches in depth of water passing over it in the rains, and not more than 1 inch or 1½ inches at other seasons. Thus, ordinarily, merely the surface water passed over it, and the water was cleaned of leaves, straw, and other substances, as well as of silt. The water was almost purified. The openings of communication, *ab*, are at the foot of the dividing walls of the chambers. The water thus passed on by means of pressure alone; there was no surface velocity. The water in the first two chambers was almost dead still. The end wall, MN, of the trap was made as short as possible. It was strongly supported by the side wall of the escape channel, and all danger of accidents was thus removed.

Other minor improvements were carried out in the construction of this trap. It had been found to be very difficult for a man to walk down the steep slippery floor of the silt-trap to the gates, which it was often necessary to do. Steps were therefore made in one of the angles of the first chamber of the new trap, and a small flat cut along the floor and through the openings, along which a man could walk. Advantage was taken of the side walls of the escape channel to throw a wooden platform across immediately over the gates, not shown in plans. Holes being cut into this immediately over the end of the bars of the gates, poles were kept ready slung through them, so that the bars could be struck and the gates thrown open at any moment.

After the silt-trap was built it was found that the action of a principle in hydraulics had been overlooked. The length of the dam had been calculated strictly so as to allow of the passage of the greatest supply of water over it at a certain depth. The tops of the side walls were fixed with regard only to this and the depth of the water in the canal. The velocity of communication through the chambers was overlooked, and the heaping up of the water in the first two chambers was so great owing to this, that the walls had to be raised to meet it. The different degrees of level at which the water stood in the three chambers, was distinctly marked to the eye. Measurements of this would be interesting and useful.

The still water in the first chamber of the silt-trap acts as a dam to the water in the canal. If possible, there ought always to be a fall in the canal immediately above the silt-trap.

Should it become necessary actually to purify the water by means of filtration, as may yet be the case for the supply of the rising town of Dehra, an apparatus for the purpose could easily be adapted to the silt-trap. The dividing walls might have cisterns at their feet, sunk below the level of the flooring, which they would span by means of arches. Those cisterns would be filled with gravel, sand, and animal charcoal, and covered with perforated zinc plates, to prevent these materials from being

* This form of gate was devised by Lieut. Edmund Walker, of the Bengal Engineers when superintendent of the canals in the Doon, to whom also most of the improvements in the construction of the silt-traps are due. By his death, which took place before Delhi, in July, 1857, the Indian Government lost one of its most promising officers.

washed up. The water would be forced to pass through the cisterns, and would be completely purified.

The operation of filtration would however be slow, and the silt trap would have to be enlarged to meet this. In fact, filtering traps would be best kept apart from the irrigation works of the canal, in which rapidity of discharge is the great point sought. There ought to be a separate construction for it.

THE INSTITUTION OF NAVAL ARCHITECTS.*

Session 1865.

On the Comparative Merits of the Longitudinal and Vertical Systems of Iron Shipbuilding, by B. Jensen, Naval Architect of Dantzic.

After reviewing the practical difference between building ships in wood, and constructing them in iron, and the tendency to import into the latter ideas derived from the former, Mr. Jensen proceeded to remark on the slow progress of the adoption of the longitudinal system in iron shipbuilding, notwithstanding the proof of its strength and capabilities evinced in the case of the Great Eastern. He stated that he was now building the largest screw steamer but one in Dantzic, and proposed to give a description of her. Prefacing this with a summary of the advantages of the longitudinal system, and of the defects of the vertical method of building, he proceeded to give a detailed comparison of her construction, weights, and quantities, with a vessel of the same description built on the usual plan in strict accordance with Lloyd's rules. The principal dimensions, &c., are as follows:—

SS., 600 tons B.O.M.

	ft.	in.
Length between perpendiculars	185	0
Breadth, moulded	26	0
Depth of side	16	8
Depth of hold	15	9

Engines, vertical, overhead, direct-acting, 90 H.P.

The longitudinal framework does not extend throughout the whole length of the vessel, but only from the stem to the after engine-room bulkhead, a distance of 153 ft. 6 in. The comparison of weights is as follows:—

	Lloyd's Rules. cwt.		New Ship. cwt.
Transverse framing	410	...	221
Longitudinal framing	172	...	306
Skin	554	...	494
			1,021
Difference in favour of new ship 10·4 per cent.	...	...	115
	1,136	...	1,136

For sectional area, Mr. Jensen stated the comparison as follows:—

	sq. in.
Lloyd's Rules	55,076
New ship	59,956
Difference in favour of new ship, 8·9 per cent.	4,880

Mr. Jensen added that if the plating had been made of the same thickness as provided by Lloyd's rules, of which, for reasons stated, he did not approve, the gain in weight would only have been 3·6 per cent., but the gain in transverse section would have been 17 per cent.

On the Composite System of Shipbuilding, as applied to Vessels of War, by Alexander M'Laine, Associate.

After remarking that vessels constructed solely of wood are not likely again to be built for the purposes of war, and that it still remains necessary to use wood, in order to secure the protection of copper or yellow metal sheathing, Mr. M'Laine further observes that the strength of an iron vessel is in her skin, and not in her framing; hence the solution of the problem is not to be sought in an iron frame with a wooden sheathing. Moreover, he attributes the rapid destruction of iron, exposed even directly to the influence of copper sheathing, chiefly to the voltaic effect of the galvanic battery, produced by the infiltration or leakage of water impregnated with copper into the space between the iron skin or frames, and the outside planking. He thence draws the conclusion that, if the space last mentioned could be kept perfectly clean and dry, without allowing the foul leakage to come in contact with the iron, the mischief would be in a great measure avoided. The difficulties incident to keeping a vessel perfectly tight are very serious, and the author proposed, in preference, to keep the leakage free from the iron of the structure by building vessels with keel, stem, sternpost, frame and outer planking nearly the same as those of an ordinary wooden vessel; but instead of the ceiling or inside planking being composed of wood, it is to be constructed of iron, united all round at the bottom and heels of the vessel, and made thoroughly water-tight, forming a complete inner skin of iron, with beams, stringers, keelsons, bulkheads, platforms, &c., also of iron. The greater part of the wooden frame to be merely of dimensions sufficient for bolting the wooden planking to, and to be inserted between iron frames riveted all round the outside of the iron ceiling. The wooden frames to be fastened to the iron frames by galvanized iron fore-and-aft bolts, either screwed or plain. The wooden floorings to be made deep in the throat and stiffened with plates on each side, riveted to the angle-iron frames, or iron floors to be fitted inside the iron ceiling to supply the requisite transverse strength. The apron, inner post, and dead wood to be inserted between, and bolted to large angle-irons, riveted on the iron ceiling. The outer planking within the influence of the copper sheathing to be fastened to the wooden frames with screw treenails, or with yellow metal bolts. The top timbers of the frame to be, by preference, composed of teak, and in the wake of the armour plating, the spaces between the frames to be filled in solid with teak, or with any other suitable material; the iron ceiling to be also increased in thickness, and additional webframes to be introduced at intervals to resist shot and strengthen the vessel. Owing to the iron ceiling in the system of construction described being perfectly tight, no foreign matters could get into the spaces between the frames to decompose in the bilge water, and generate gases injurious to animal life and productive of decay in timber exposed to their influence. These frame spaces, which would be kept constantly dry by frequent pumping, would, therefore, be eminently eligible for the introduction of a thorough system of ventilation through the vessel, by driving a current of fresh air taken from above, through the box keelson, thence through apertures in the bottom of the keelson opening into each space between the floors, then up through the spaces between the frames, and out into the 'tween decks, through apertures in the iron ceiling, grated over and fitted with adjustable covers, capable of regulating the amount of the ventilation. The ventilation described would be of immense importance in furnishing the crew, in any weather, with a regular and easily controlled supply of fresh air, and would also, at a small expense, immensely increase the durability of the vessel, and a three-horse-engine would probably supply power sufficient for the ventilation of a ship of 3000 tons register.

On the Construction and Sheathing of Iron Ships, by T. B. Daft, C.E.

After pointing out the practical failure of paints and other compositions to preserve iron vessels from fouling, or even to remain in close adherence to the surface, Mr. Daft brought forward a proposal to re-arrange the plating of iron vessels in such a way as to produce a fair flush surface so as to afford a good foundation for sheathing. This he would obtain by leaving a space or groove between one plate and another in the skin of the ship; these grooves to be "caulked" or filled in with teak or other suitable material, pared off flush. Butt-straps would thus be required longitudinally as well as vertically; but Mr. Daft considered the method to be more advantageous as well as stronger than the ordinary plan of butts and laps, besides conducing to speed. Without sheathing, he considered such a surface preferable for the retention of paint or composition. But he preferred to sheathe, and with zinc. He stated that this metal not only preserved the iron galvanically, but that the slight exfoliation of the zinc itself, due to the voltaic action of the iron in contact with it, caused it to exceed both copper and

* See page 182.

yellow metal in cleanliness. He produced a specimen which had been immersed for twenty-eight weeks in the sea off Southend. The bare iron was coated six or eight inches thick with weed and barnacles. The zinc was clean, and had only lost a twenty-fourth part of its original thickness. A specimen of a similar experiment had been deposited in the Naval Gallery of the South Kensington Museum.

On a Proposed Method of Combining Wood and Iron in Composite Ships, by MICHAEL SCOTT, C.E.

The author stated that his method combined the strength of the iron ship with the capability of being coppered afforded by the wooden ship. The leading features of the plan were as follows:—

First, the iron structure—This with the following exceptions was described generally as being similar to an ordinary iron ship. The exceptions were—1st. The frames formed of T iron, stronger and spaced further apart. 2nd. Amidships and extending to the furthest forward and the furthest aft bulkheads, the vessel only plated to the lower turn of the bilge, the ends only being plated complete. 3rd. The joints of the plating all butt-joints; the plates close to the frames; liners dispensed with, and the butt strips outside. 4th. Extending from the upper edge of the bottom plating to the lower edge of the sheer strake, a series of diagonals formed of flat bar-iron riveted to the plates at top and bottom to the frames, and to each other wherever they cross; a framework is thus obtained having the strength of an iron ship, but it is only a skeleton which requires flesh and skin in order to become a complete body.

The next step, therefore, is to fill the spaces between the frames solid with two thicknesses of wood, the outer thickness composed of timbers running parallel with the frames, and the inner thickness of timbers running at right angles to the frames. The outer thickness would be creosoted and caulked. The inner thickness may, or may not, be similarly treated. And both thicknesses would be fastened to the diagonals with iron bolts passing through all. If preferred, both thicknesses of wood might be placed vertically, the one covering the seams of the other. In order to bring the surface of the wood outside, flush with the surface of the diagonals, the spaces formed by these would be filled with thin boards in two thicknesses, one set of boards filling between the inner diagonals, and another set between the outer diagonals. Over all would come the outside planking like that of an ordinary wooden vessel. It would be fastened by treenails or by copper bolts passing between the diagonals and frames, and through the several thicknesses of wood. Mr. Scott then proceeded to describe the detail of the construction of the bow and stern. The author considered it an important feature of his method that, whilst bolts are employed to keep the wood in place, the strain to which the vessel is exposed are not taken by these bolts. The internal capacity is as great in proportion to their displacement as in iron vessels, and greater than in wooden vessels.

On some Recent Experiences in Marine Engineering. By ROBERT MURRAY, C.E., I.N.A.

THIS paper was intended to give a record of Mr. Murray's experience on certain controverted points of marine engineering, namely, surface condensation, combined cylinder engines, superheating, the relative advantage of screws as compared with paddles, and the durability of shafts.

Surface Condensers.—It was found that the water, while free from salt, was apt to become very foul, the result being that the tubes of the condenser got blocked up, while the boiler was exposed to even more rapid deterioration than under the influence of hot brine. There was a set off, but not an adequate one, in a diminished consumption of coal. Mr. Murray thought that, on the whole, there was little or no saving in their use at present.

Combined Cylinder Engines.—By a comparison of the performance of the Poonah, Delhi, and other vessels of the Peninsular and Oriental Company, with the Saxon and Roman of the Cape Mail Company, Mr. Murray was led to the conclusion that there was no such advantage over the single cylinder as would compensate for the increased weight and complexity of the combination.

Superheating.—Mr. Murray stated that it might now be considered as certain that this process is desirable for all vessels which make long voyages, and which use expansion in the cylinders to any considerable extent. In the smaller class of coasting and river steamers, where the trip was short, and the engines not worked so expansively, superheating did not answer so well. In any case the temperature of the steam at the superheater should be limited to 320° or 350° at the utmost.

Screw v. Paddle, for Ocean Steaming.—Mr. Murray considered that this question was by no means in a settled state, and discussed in detail the circumstances under which either method had advantages over the other. He remarked that screw vessels were often placed under circumstances disadvantageous for comparison by being underpowered.

Shafts.—Mr. Murray stated it as an established rule, that shafts, whether paddle or screw, will not last beyond a limited time, failing sometimes after five years' work, in other cases lasting ten or twelve years, but always being deteriorated by use. After discussing the cause and manner of this deterioration, he stated circumstances which led him to form a favourable opinion of the recent introduction of steel instead of iron for the shafts both of paddle and screw engines.

On a Practical Method of Measuring the Circle described by a Ship, or of ascertaining the Smallest Space in which a Ship can turn; by F. MARTIN, I.N.A.

AFTER pointing out the importance of measuring, with greater accuracy than can be obtained by mere observation of the wake, the diameters of the circles made by a vessel in turning, in order to test her steering power, Mr. Martin describes the construction and use of a simple instrument for taking these observations with accuracy. It consists simply of a wooden quadrant, with a batten or index, carrying wire sights. A base is measured, fore and aft, on the ship's deck, and at the forward extremity a line is drawn athwartships, and marked by means of two battens fixed vertically to the ship's side. The quadrant is placed at the other end of the base. When the helm is hard over, a box or other object, visible at a considerable distance, is thrown overboard, and the completion of the semicircle is known by the box coming again in line with the battens. At that moment the sights of the quadrant are brought to bear on the object, and the angle which the object makes with the fore and aft direction, is then read off. The solution of a right-angled triangle is all that remains to be done in order to find the diameter. An auxiliary table for the purpose had been calculated by the author. The author observed that the instrument cost very little, and was very simple and durable. He added, that he had used the method repeatedly in testing the power of Lumley's patent rudder when fitted to the Columbine.

On some Results of the Lumley Rudder in H.M.S. Sheerness, by HENRY LUMLEY.

AFTER mentioning the adoption of this rudder in several large vessels of war, and among others in the American iron-plated frigate New Ironsides, the Dutch ship of war Java, and others, and quoting reports from the commanders of H.M.S. Lizard and Columbine, the former to the effect of its especial value in narrow and tortuous channels, the latter of its efficiency in all weathers during a protracted cruise of more than 26,000 miles, under both sail and steam; the author proceeds to give an account of an experiment at the Maplin Sand, made in H.M.S. Sheerness, a steamer fitted with disconnecting paddle-wheels which can be separately reversed. Steaming ahead, full speed, several circles were made to starboard in 2 m. 45 sec., and to port in 2 m. 35 sec., the diameters of the circles being about three times the ship's length. From dead stop to full speed the circle was made in 3 m. 15 sec. With one paddle working ahead and the other astern, the circle took nine minutes to make, the rudder being left to itself. With the rudder helping the paddles—that is to say, starboard wheel reversed, and port wheel moving ahead, the rudder being to starboard—the time was reduced 4 m. 55 sec. Comparing this with the previous experiments it was seen that the use of the rudder was far more effective in bringing the vessel round than the attempt to turn her by driving her sides against the water, even with the powerful leverage of both paddles.

On the Practical Limits of the Rolling of a Ship in a Sea-way, by W. FROUDE.

THE mathematical theory of the unresisted rolling of ships implied that all ships whose natural period of oscillation in still water was the same, would perform the same series of oscillation if exposed under the same initial condition to the same series of waves. And notwithstanding the modifications which must be introduced into the abstract results of the theory, by importing into it the consideration of resistance, it seemed that we might still predict this identity of behaviour, under circumstances having instruction relative to the probable behaviours of armour-plated ships. For, if with two ships—one of them armour-plated—of identical dimensions and form, identity of natural period, be secured by giving to the ship with the less widely distributed rates, a duly lessened moment of stability, both would experience precisely the same resistance in performing the same movements, since the velocity would be by hypothesis the same. And there was plausibility in the inference that their movements, which, irrespective of resistance, would be undoubtedly the same, would experience the same modifications in consequence of the sameness of resistance. But an important cause of difference underlies this apparent sameness of conditions, and this, when traced, supplies a means of comparing the maximum angle of rolling which different vessels would reach each under the circumstances most unfavourable to it. In tracing this it is necessary to refer to the characteristic features of the two principal types of rolling as it would exist if clear of resistance, in order to observe how resistance operates in relation to each of them.

1.—In the cumulative type, which is due wholly to wave impulse, and embodies its maximum possible effect in each particular case, a series of oscillations begins from nothing, grows by successive steps to a maximum, and dies out by similar gradations, when the series re-commences, and is repeated throughout. The number of steps in the series, and the range of the maximum roll attained, are alike longer in proportion as the period of wave recurrence more nearly equals the ship's natural period of rolling; and when the two periods are equal, the transit of each wave slope impresses on the ship an exactly timed impulse, such as to increase the range of her oscillation by an angle equal to half the maximum slope of the wave; the periods of alternate maximum inclination occuring when the ship is at the crest of the wave, when she leans in the direction of its motion; and at the bottom of the trough, when she leans against that direction; the range increasing oscillation by oscillation. The operation of resistance here, neither sensibly alters the period of the ship's oscillation, nor displaces its phase in relation to the wave phase, but simply limits the accumulation of range by abstracting the energy which the wave impulse imparts. The limit thus attained marks the maximum oscillation of the cumulative type.

2.—In the type of oscillation of fixed range in which a ship may become engaged with a given wave series, the oscillation must be derived from some previously impressed impulse, which must have a due relation to the ratio of the ship's natural period to the wave period, and must be so duly timed in relation to the wave phase, that the ship's period becomes conformed to the wave period by the auxiliary recurring impulse. The masts are upright at the wave crest and in the trough, and their greatest inclination is at the mid-height of the wave; leaning towards the slope or from the slope, according as the ship's natural period exceeds or falls short of the wave period. The fixed range of oscillation is greater in proportion as the ship's period more nearly equals the wave period, and when the two are equal would be infinite but for resistance. The operation of resistance here, while it contracts the fixed range attained by the oscillation, at the same time displaces its phase in relation to the wave phase in such a manner that when the periods of the ship and of the wave are equal, the relation of the phases becomes the same as that appropriate to the same condition, under the cumulative type.

The maximum oscillation attained under both types must therefore be the same; so that it is sufficient to determine that maximum under the cumulative type, where its determination happens to be more simple and easy.

The maximum attained may be practically gauged for any given ship, by comparing the rate of degradation which resistance imposes on her oscillations in still water, with the rate of accumulation which wave impulse would impose on her if free from resistance. That rate of degradation, necessarily very rapid for oscillations of large range, proceeds by shorter steps for those of shorter range; and we may find some range such that the decrement of range appropriate to it shall exactly equal that constant increment of range which each synchronising wave recurrence tends to impress on her. Now, if we compare the still-water oscillation of the two identically formed but differently weighted ships, that of the armour-plated ship having a large moment of inertia, will obviously lose range by the smaller steps, since the energy abstracted by resistance during a given swing will obviously bear a smaller ratio to the whole energy embodied in that swing, with her than with the other; hence it will be in an oscillation of more extended range that she will experience a loss of range equal to that which the wave tends to impress on her. The ship with the more extended weights will, under the given circumstances, roll more deeply than the other. It follows that on the whole, an armour-plated ship, when engaged with sychronising waves, will roll more deeply than a sister ship, differing only by having her weights more concentrated, so that it is on the whole unadvisable to attempt to steady a ship by "winging out the weight;" and though it is wise to secure ease of motion as far as possible by raising the ship's centre of gravity, yet it is only if the resistance follows some power of the velocity less than the square, that the maximum angle reached is thus at all reduced. Hence, since the inevitably considerable distribution of weights in every ship renders it impossible to reduce the radius of gyration at pleasure, and since prudence forbids the elevation of centre of gravity beyond a certain limit, the only remedial arrangement, certainly within our power, and certainly efficacious, is to increase the co-efficient of resistance, which can be effected to almost any extent by the addition of extended bilge pieces, which if framed with a due attention to strength, involve no necessary disadvantage except a small increase of the ship's resistance. For though, on hasty reflection, it may be thought that the proper motion of the particles of water of which an ascending wave slope consists, tends to seize the bilge pieces nearest the wave, and to cant the ship's side upwards by acting on it, yet first, these proper motions all take place with a velocity relatively so slow that its effects must be all but inappreciable compared with the moment of statical force which the wave slope would put in operation. Moreover a pair of equal bilge pieces placed each on the turn of the bilge, so that their planes would meet near the ship's centre of gravity, intersecting at right angles, will in fact each almost precisely neutralize the disturbing action of the other, small as that is. This is readily seen on inspecting a diagram illustrative of the anatomy of the wave, in which it appears that a pair of planes thus placed and hinged at their intersection, so as to open and close like a book, and intersect each other at right angles in their mean position, tend simply thus to open and close, each equally deviating from its mean position as the wave passes, causing meanwhile no disturbance among the particles which they touch; and thus, the corresponding bilge pieces, endeavouring to follow the motions of these planes, would each at the same moment and in the same degree tend to elevate or to depress the side of the ship to which it is attached.

On a New Method of Ventilating Ships of War, and of admitting Water into them and clearing it again; by Rear-Admiral Sir EDWARD BELCHER, C.B.

AFTER describing the measures taken by him to stow and preserve the provisions, water, and stores in H.M.S. Etna, and in the Erebus and Terror, and to secure ventilation in these vessels, the author turned to the methods more peculiarly adapted to the present day, when iron is used for the building of ships, and is available for their fittings. Passing in review the disadvantages attending the present system of storing water in small separate tanks of a couple of tons each, filled and emptied through a hole in the top, difficult to get at, and not contributing in any way to the strength or safety of the ship, Sir

Edward proceeded to recommend the adoption of fixed cells, adapted to contain each about 20 tons, occupying a space of 8 × 8 × 12 feet, and securely fitted with a man-hole, capable of being closed, so as to be completely water-tight. He then described the manner in which thorough ventilation might be secured, and how, if necessary, these tanks or cells might be filled with air, to the exclusion of water, in case of injury to the vessel. Similar man-holes, with well-packed covers, were recommended to be fitted to every separate compartment of the vessel, such as wings, coal-bunkers, and the like. He also discussed the arrangements to be made for flooding the magazine when necessary. The water would be obtained from these tanks by simply leading the pump hose into them. For rum, Sir Edward proposed a different arrangement, namely, forcing air in at the top of spirit tank, and sending up the rum by displacement, through a tube opening into the bottom of the tank. But the author considered the most important point of the cellular distribution of the ship's hold to be the control which the crew of a vessel would have over any water entering by means of leakage, for by boxing in any portion above the leak, and forcing air in from above, the water would be displaced, and the hold more or less completely cleared of it.

On the Design and Construction of double-ended Ships of War, by John Kennedy.

After stating the chief qualities which he considered that a man-of-war should possess, namely—1. Good form of immersed body for propulsion. 2. Complete command of steering. 3. Great transverse and longitudinal stability as well as buoyancy. 4. Strength combined with lightness. 5. Roominess; and 6. Stateliness of appearance—Mr. Kennedy described some draughts of vessels designed with the view of meeting all these requirements in a very high degree. He submitted drawings and a detailed account of a first-class 20-gun frigate, 4791 tons B.O.M., and of a first-rate ship of war, of 11,856 tons, B.O.M., both double-ended—not bow and stern alike—but with two propellers and two keels having an arched floor between them, but terminating forwards in a beak or ram. Transversely, the vessel is divided by its chief vertical section at $\frac{4}{10}$ths from the bow, into a ship-formed forebody, and a fish-shaped afterbody. A reserve floating power, proportioned to the displacement, is given to the ship above the plane of flotation, covered in by a substantial platform, and protected by plating or otherwise. The whole of the available space in the hold between the upper deck and a certain distance below the defensive armour in the bottom is proposed to be constructed of small cells like a honey-comb, of very thin and light metal. The vessel is intended to have an outer skin of zinc some 3 or 4 inches outside the proper shell of the ship. The construction and fastening of this skin was fully described. It is to be covered with a composition of lime and oil to prevent fouling. Details of the dimensions and arrangement of the masts and yards were also given for a first-rate man-of-war on this system.

On an Improved Hydraulic Ship Lift, by Captain F. H. McKillop, R.N.

Captain McKillop, after remarking on the necessity of dock accommodation abroad, and the impossibility of procuring it in certain countries, and on the disadvantages of floating box-docks, described Walker's patent hydraulic ship-lift or floating dry dock, consisting of two series of pontoons, having a skeleton tray suspended between them and attached, by means of heavy pitch chains, to hydraulic presses, by which it, and the vessel upon it, can be raised to a sufficient height. The pontoons in each set are held together by longitudinal iron keelsons, so that the failure or removal of any one will not cause mischief. The advantages claimed for it were—1. Complete dryness; 2. Ready access to all parts; 3. Simplicity, and easy renovation, from its constituent portions being duplicates one of another; 4. Dispatch in its use. The cost for such a dock, 300 feet in length and 51 feet inside breadth, is estimated at from £30,000 to £40,000.

CREEDS AND TEMPLES: THEIR RELATION TO ONE ANOTHER IN PAST AND PRESENT TIMES.*

By H. H. Statham, Jun.

With the fall of monasticism, however, and the rise of a purer faith under the influence of the Reformation, we again witness the decline of temple architecture, which has never since reassumed its old power, or produced a style peculiarly its own; for that of St. Paul's, and other great churches of the Renaissance period, besides that it was in great measure a copied and not an original style, arose from feelings and motives quite unconnected with religion; and it is not necessary to go into any proof of the neglect of internal beauty and decoration in churches since the Reformation. In the present day we have changed all this, and we pride ourselves on having resuscitated church architecture, and look with a smile of pity on the works of our grandfathers. But have we after all so much right to laugh at them? Are we in such a very satisfactory state ourselves?

It is remarked by Dean Stanley, in his lectures on Ecclesiastical History, that no word has been more debased in its signification than this same word "ecclesiastical." "It has come to signify," he says, "not the religious and moral interests of the social community, but often the very opposite of these—its mere accidental, outward, ceremonial machinery. We call a contest about the abolition of vestments ecclesiastical, not a contest about the abolition of the slave trade." And surely we may see this feeling but too well imaged in the state of church architecture in the present day. For what is meant by the term "ecclesiastical architecture" by the majority of those who make most use of it? Not the provision of buildings suitable to the worship of the present day, and expressing in their style the more enlightened and reasonable faith which has succeeded to that of the Middle Ages; but rather of buildings suitable only to a form of worship in which ceremonies and symbols were all-important; and the spirit of which exists no longer but in the ideas of a few enthusiasts in whom love of ecclesiastical precedent has over-ridden every other feeling. We have large and deep chancels for the accommodation of a priestly hierarchy which no longer exists, fitted with stone *sedilia* on which no one would think of sitting, and in the most recent instances railed across the front to protect the clergy from the intrusion of congregations who really, on the whole, are very orderly and well-behaved; receptacles for holy water which has long ago lost its efficacy; fonts placed, "for symbolical reasons," near the west door, so that if a baptism is held in the course of the ordinary service the congregation may choose between remaining with their backs to the minister or sitting on the backs of the seats. We are so used to these things that we almost forget their absurdity, but it is amusing enough to see the same thing in another country. It appears that there is a sect in the Russian church who are possessed by the same mania. I quote again from Dean Stanley: "These churches have not a single feature that is not either old, or an exact copy of what was old. The long meagre figures of the saints, the elaborately minute representations of sacred history, are highly characteristic of the more than restoration of Mediæval times. The church resounds, not with the melodious strains of modern Russian music, but with the nasal, almost puritanical screech, which prevailed before the time of Nicon, and which is by them believed to be the sole, orthodox, harmonious, and angelical chant." But for the name of the Russian patriarch Nicon, this might be a description of one of our own paradises of Ecclesiological Archaism. Some of our "ecclesiastical" architects might surely advertise for a draughtsman in the language of Falstaff,—"O for a fine thief, of the age of two-and-twenty, or thereabouts!" For even the accidental faults of the style must be copied. Because the Mediæval architects occasionally committed the gross artistic blunder of bringing down a heavy buttress upon the roof of a porch, therefore this shall be perpetuated in a modern church, without the slightest reason or excuse whatsoever: because they decorated their internal walls with artificial jointing in coarse red lines, we are exhorted to follow so noble an example: because they could not draw the human figure, and left ample proof of their inability, our stained-glass windows shall exhibit portraitures of saints, looking, as a modern writer has said, "like starved rabbits with their necks wrung;" and our chancel

* Concluded from page 174.

walls shall be painted or inlaid with grotesque figures, profanely put forth as representations of the Deity, and which at least do not transgress the second commandment, as they are certainly not the likeness of anything in heaven or earth, or the waters under the earth. Quitting, however, this painful subject, let us consider what are the real objects to be attained in a modern church service, and what the real requirements of the plan.

The public worship of the present day may be defined thus,—it is the meeting together of a number of people professing the same faith, for the expression of unanimous prayer and praise, according to a prescribed form, the mass of the worshippers being led in their prayers by ministers ordained for the purpose, and in their musical service of praise by a certain number of people more or less trained (generally *less*). There are, then, three divisions of worshippers to be provided for—the clergy, the choir, and the people. And first, with regard to the people, I must protest against an idea that has lately been put forth, that their part of the church is to be treated as an *auditorium*, and planned, in fact, on the same principle as a theatre. This can only result from a very superficial view of the subject; for surely there is a great difference between the meeting of a number of people to witness a dramatic performance, in which they take no part whatever, and their enjoyment of which depends upon their proper opportunity for hearing and seeing, and the meeting of the same people for an expression of their own feelings, in which they ought all to join, and the forms of which they all have, or may have, in print before their eyes. That it is practically necessary that the clergyman's voice should be heard I admit; but that the church should be planned as if this were the one object, and as if the people were met to hear a speech or see a spectacle, I entirely deny. The principal point to be observed is, I think, that all the congregation should have the reading-desk, the pulpit, and the communion-table within their view; and on this account I think that three-aisled churches are, on the whole, to be avoided (unless the side-aisles be used only for passage) as the view can only be rendered clear to all the people by the use of thin iron supports for the clerestory walls, a device fatal to architectural effect. Long transepts, also, are of course quite inadmissible. I should consider a separate baptistery a very desirable addition, as the practice of holding baptisms during the course of the ordinary service is being disused, and it is very comfortless for a dozen or so of people to meet in a large and often cold church. With regard to our second division, the choir, it is only necessary that they should be placed where they will be tolerably conspicuous and well heard; and that they should be divided on opposite sides of the church for antiphonal singing, an effect too beautiful ever to be given up. They are generally at present placed in the chancel, in front of the communion-rails, thus entailing the double advantage of placing the singers where their voices are much more confined than they would be in the nave, and of removing the clergyman, during the Communion service, as far as possible out of the hearing of the congregation: an amusing instance of the blunders people make by following precedent; for the choir sat within the chancel in the early times, not because that was the best place for them as singers, but because they were always members of the clergy, and therefore to be separated from the people. The more the choir are made to feel as a part of the congregation, the better, I suspect for their devotional feelings. The clerical requirements are, firstly, the chancel, which in the present day need only be large enough for the celebration of the Protestant Communion service, and for which the simple apse of the early churches furnishes the best possible model; the reading-desk, which should be placed in a convenient position on one side of the apse; and the pulpit, which must be placed where the clergyman may be best heard, the sermon being the only part of the service where the people depend entirely upon hearing him; with this limitation, that it should never be planted conspicuously in the centre of the church, as if it were the point to which everything else was subordinate. A vestry, also, is of course required for the clergyman, which I think should be a tolerably large room, capable of containing a bookcase, if necessary, and of affording comfort and convenience; not a mere cage, scarcely large enough to turn round in.

The introduction of a larger and finer class of organs into our churches than have hitherto been found there, claims some consideration, though this has been strangely neglected; and while drawings are furnished by the architect for every bench and hinge, the largest and most important piece of furniture in the church is left to the tender mercies of the organ-builder's joiner. The usual position of the organ, in a chamber built out from the chancel, is almost the worst in which it could be placed. It should be where it has free space to sound, not where the sound is driven down and smothered the moment it is emitted. In addition to this evil, the placing of the instrument between two or more outside walls, and with a roof close over it, exposes it to every change of temperature, which not only alters the tuning, but makes sad havoc with the delicate internal mechanism, and not a few instruments are now being ruined by being placed in this position. Where it is necessary to place an organ so, there should at least be a dry area in the wall, and a ceiled roof over.

The question of style is too important, and at present too difficult a one, to be tacked on to the end of a paper; but I may venture a few remarks on general principles. Although I do not at all advocate the direct revival of the Gothic style, or think it fitted to express the feeling of the present day among the mass of the people, I nevertheless think it very important to preserve the feeling for breadth of effect and deep shadow in the mouldings and ornamentation so conspicuous in that style, and so admirably suited to our northern climate, of which it appears to me to have been the natural outgrowth; and while making all due concession, in the design of a church, to nineteenth century ideas of comfort and civilization, I would avoid everything like littleness and tawdriness of effect. A church is not a drawing-room, nor is it to be fitted up, as a writer suggested lately, with curtains and draperies and arm-chairs, and everything with which the most ordinary associations are connected. It is a legitimate field for the display of architectural art in its highest form,—architecture of that lasting and durable character that is best described by the word "monumental." I should very much wish to see the domed form of roof more used. It is a difficult form to manage externally, on account of all its lines, on a near view, receding so fast from the eye; but internally there is, I think, no effect comparable to it, and a church is essentially a building for internal effect. Galleries, I think, should be avoided, if possible. However well managed, they detract very much from the general effect, and principally, I believe, for this reason, that the impression produced on the spectator by a fine and lofty church is much enhanced, even without his knowing it, by the evident fact that it is so much more lofty than is really necessary; that the piers and arches, the dome, or the high-pitched roof, are carried up to that height purely for artistic effect. Place a gallery there, and you immediately weaken this idea by suggesting that, after all, the extra height is necessary to give room for the upper tier of worshippers, and the whole thing is more or less utilitarianized.

In looking back at the history of church architecture, there is one consideration, at least, which is encouraging—there is something left for us to do. As I have endeavoured to show, there has not yet been any style complete and artistic in itself, and expressive of the highest and purest form of Christian worship. It is left to us to originate such a style, and I see no reason why we should not, if we go the right way about it. As the descendants of the builders of Lichfield, Canterbury, Wells, and Salisbury; as the possessors, since then, of a literature second only to that of the Greeks, we surely are not by nature an in-artistic nation. But I suspect the secret is that we have no fixed principles, and take no trouble to fix any. Occasionally, writers like Garbett, Fergusson, and Huggins, startle us by suggesting that all is not quite right, in spite of the architectural activity going on around us; but no lasting impression is produced, and things seem to go on much on the same principle of accidental selection, or no selection at all. It may be answered that the Mediæval builders did not trouble themselves about principles. I believe they did not; but they nevertheless worked on a principle—that of elaborating the details best suited to the climate, upon the plan best suited to their requirements, and of always doing the very best they could according to their light. If they were not conscious of these principles, it was simply that they were never tempted to overstep them. But it is utterly impossible, in these days of travel, to place ourselves in the same position; and it is only, I believe, by attending to principles, and by fixing these principles on a certain basis, that we can guard ourselves against the indiscriminate copying of everything that strikes our fancy for the moment. Perhaps the study of the history of previous styles, with their surrounding circumstances, is not the worst way of attaining this; and I believe that one very great step towards regulating and restraining our tastes would be an increased attention to the study and drawing of the figure, as an accessory to architecture, in that highest style of art of which the Greeks have left us almost unapproachable examples; and as their temples had friezes and sculpture representing passages in their mythology, I see no reason why ours should not also be adorned with bas-reliefs, in like manner, representing subjects from Biblical and ecclesiastical history (taking the word ecclesiastical in its widest sense). The healthy influence, at any rate, of such a study would perhaps deliver us from the incubus of symbolism; would render it impossible for our eyes to be pleased with the sharp, angular, bristling forms, the quirks, the crinkle-crankle, the utter absence of repose or beauty of line which characterise much of what is called "modern Gothic," but is based upon principles (if any) widely different from those of the real Goths; and would surely do more to resuscitate church architecture than the delineation of starved-looking angels with wings red on one side and green on the other, or than the most careful arrangement of flat brickwork in the most elaborate coloured patterns.

THE STEAM BOILER ASSURANCE COMPANY.*

THE total number of inspections made by the officers of the company, in the course of the year, was 23,849, of which 776 were internal, and 2321 thorough examinations. Although the latter considerably exceed those of any former year, they yet fall short of what is desirable, on account of the comparatively few opportunities afforded; the owners of boilers being, in general, unwilling to allow any stoppage of their machinery for this purpose. The opportunities for thorough examination are, therefore, mostly limited to annual holidays, and the occasional stoppage of work from accidental causes. In order to impress more strongly upon the assured the importance of these examinations, circulars have been issued drawing attention to the subject, and at the same time pointing out the necessity of having the flues and undersides of boilers properly cleaned, without which a satisfactory examination is impossible. Frequently, when an inspector has been sent a long distance by special request, he has found, on arrival, that no preparation had been made, so that both his time and the expense of his journey have been thrown away. I have before called attention to this subject, but its importance induces me to do so once more.

The principal defects reported were as follows,—

Fracture of plates and angle iron	484
Corrosion of ditto	861
Safety valves out of order or over-loaded ...	507
Pressure gauges out of order	297
Water gauges ditto	364

The attention of the assured has been directed to these and many minor defects, and remedies suggested when necessary. Having so fully explained the causes of such defects in previous reports, I shall confine my remarks on the present occasion to such facts as present some novelty, or which, for other reasons, seem deserving of more particular notice.

Fractures.—The dangerous defects under this head which frequently occur on the undersides of boilers, near the middle, have been before described; but there are one or two points in reference thereto on which it may be well to say a few words. I have explained that in the case of boilers with internal furnaces, such fractures are attributable to unequal expansion, and may generally be prevented by so arranging the external flues that the products of combustion, after leaving the internal flues, pass first along the underside of the boiler towards the front, and thence return by the sides to the main flue and chimney; also, that the insertion of vertical or diagonal water tubes in the internal flues, by facilitating circulation of the water, is conducive to the same end. That explosion does not more frequently take place when such fractures occur, is evidently owing to the internal flues acting as stays or tie-rods, and thus relieving the plates of the shell of a portion of the longitudinal strain. With plain cylindrical boilers, however, having no longitudinal stays, the risk of explosion under such circumstances is much greater, and it not unfrequently happens, that boilers of this construction explode at the ordinary working pressure, without any previous symptom of defect. In many instances, such fractures result from the objectionable practice of running off the water for cleaning, before the adjacent brickwork has had time to cool. The consequent overheating of the lower plates causes elongation of the boiler on the underside, which then becomes convex in the longitudinal direction. On the cooling of the brickwork, contraction and another change of form take place, and the severe straining to which the plates are subjected by the alternate expansion and contraction ultimately produces fracture. When such boilers are suspended by bolts and nuts from cross beams or girders, as is common in the North of England, it has been observed, under the conditions mentioned, that the expansion of the boiler on the underside has raised the ends, lifting the nuts by which they had previously been suspended from ½-inch to inch above the girders.

Moreover, when repairing such boilers, too little attention is generally paid to the accurate fitting of the plates, and the importance of retaining the cylindrical form. Where holes do not correspond, "drifting" is resorted to, and on completion of the repairs, the boiler is often weaker than before, the plates being already strained almost to the limit of their strength. This accounts for so many boilers of this construction having exploded shortly after having undergone repairs.

In connection with this part of my subject, I may here relate a remarkable occurrence which recently came under my notice, giving further evidence of the severe strains to which boilers are sometimes subjected. The boiler to which I refer is 33 feet long by 7 feet diameter, with two furnace flues 2 ft. 7 in. diameter, made of $\frac{7}{16}$-inch plates. To each of these flues, at the middle of their length, an angle-iron ring is rivetted, with a piece of plate between, tying the two flues together. To the upper part of each ring, other pieces of plate about 15 inches broad by $\frac{7}{16}$-inch thick, were originally attached, and secured by rivets at the other end to the shell of the boiler. Having frequently had evidence of the evil effects resulting from this mode of connecting flues with the shell, I recommended the removal of the plate stays; but instead of carrying out my suggestion, these stays were merely detached from the shell by taking out the rivets at the upper end. On resuming work after these alterations, the attendant was suddenly alarmed by a loud report, accompanied by great vibration of the boiler, evidently the result of a severe blow, but he was unable to discover any defect in the boiler, or cause of the report. This was, however, repeated at irregular intervals, two or three times, on that and subsequent days, and created much uneasiness in the minds of the owners, who therefore wrote to me on the subject. On hearing the particulars, and learning on inquiry that the stays still remained attached to the flues, I again advised their removal. This was accordingly done, and there has since been no repetition of the occurrence. On examination it was observed that, although between the shell of the boiler and one of the stays there was a space of not less than ½-inch, and ⅜-inch in the case of the other when the boiler was not at work, yet both stay ends had come in contact with the shell in the course of working. It appears therefore, that when exposed to the heat of the fire, the flues, by expansion, had risen in the middle, bringing the longer stay in contact with the curved surface of the shell: as the expansion of the flues continued, a severe strain would thus be thrown upon the stay, and at certain times, when the heat was at the maximum, further expansion of the flues had taken place, sufficient to overcome the friction of the surfaces in contact, and produce lateral motion of the flues, accompanied by vibration of the whole boiler, caused by the striking of the stays against the shell.

Another instance may be mentioned, where in a boiler 30 feet long, the flues 2 ft. 9 in. diameter, made of $\frac{7}{16}$-inch plates, were found to rise ⅜-inch in the middle, the working pressure of the boiler being 50 lb. per square inch.

This motion of the flues explains the cause of grooving or fracture, so often observed in the angle-iron rings by which flues are attached to the ends of boilers, a result most frequent where the ends are too rigidly stayed.

Corrosion.—It will be observed that defects under this head are much the most numerous. Many of the boilers inspected have been found in a most dangerous condition, and there can be little doubt, that but for the timely detection of these defects by the officers of the company, the number of explosions must have been considerably increased. The three principal causes of corrosion are these—defective workmanship, dampness of the seating, and acids in the water; the remedies for which are self-evident, and need not therefore be repeated.

Safety Valves.—Thirty-one boilers were found working in great danger, owing to the safety-valves being entirely inoperative. In many other cases the valves were greatly overloaded, and I must again draw attention to the very prevalent, but most objectionable, practice of attaching extra weights to safety-valve levers. For example, I may mention one instance where, in addition to a large weight of 89 lb. attached to the lever of the valve, there was also a piece of 3-inch water pipe, a lump of cast-iron, and a pedestal belonging to the engine, weighing altogether 42 lb. To another, besides the proper weight, were attached a cast-iron ball, a piece of 4-inch pipe, the flange of another pipe, and a piece of wrought-iron. Another case of overloading is deserving of notice: at the first visit of one of the inspectors, to examine a boiler proposed for insurance, he found by calculation that a small lever safety-valve, with which it was provided, was loaded to 106 lb. per square inch, although, according to the gauge steam blew off freely at 62½ lb. pressure. The owner disputed the accuracy of the inspector's calculations, and apparently with some reason, inasmuch as steam blew off at the same time from one of Hopkinson's patent safety-valves, with which the boiler was also provided, the pressure graduated on the lever being only 60 lb. per square inch. On subsequent examination, however, it was discovered that this valve was overloaded by extra weights attached to the lever inside the boiler, and that the pressure gauge indicated 43½ lb. less than the actual pressure. The extra weights had been attached unknown to the owner, and not improbably under the impression that the actual load on the

* Abstract of Engineers' Report for year 1864.

valve did not exceed that indicated by the gauge. The insurance of the boiler was deferred for some months, in order that the valve should be correctly weighted previous to insurance; but ultimately the boiler was replaced by a new one, which the owner declined to insure.

The facility with which Hopkinson's and similar valves can be overloaded, as in the present case, or as I have known in other cases, by placing a piece of wood between the inside lever and the shell of the boiler, is a strong argument against their adoption, notwithstanding any other merit they may possess.

Another valve of the same construction was found inoperative, the valve being held down by means of an iron bar, secured by a prop from the roof of the boiler house.

The last example I shall give is one where a safety-valve was inclosed in a box, the egress from which had been closed, and an inch gas pipe attached for the purpose of testing tubes, a small tap being inserted in this pipe to admit or shut off steam at pleasure. At the time of inspection, the inspector found that the condensed steam which had accumulated in the pipe, had become frozen, rendering any escape of steam from the boiler impossible.

Pressure Gauges.—Since little reliance can be placed on the accuracy of many of these gauges, it is exceedingly desirable that every boiler or set of boilers should be provided with an indicator tap, fixed on the main steam pipe, to enable the officers of the company, at any time, to test the accuracy of the gauges, as, notwithstanding repeated warnings, the dangerous practice of weighting safety-valves to accord with pressure gauges is still very prevalent. The importance of this suggestion justifies me in repeating it.

Water Gauges.—In reference to these, little need be said. In addition to the large number reported "out of order," many others have been found in a very unsatisfactory condition. No mounting attached to a boiler requires greater attention than the water gauge, as deficiency of water is by far the most fruitful source of danger. Among the boilers insured, 101 cases of deficiency of water have been reported in the course of the year. Of these 34 escaped injury in consequence of being provided with Allen's fusible caps; the remainder were more or less injured, and have been repaired at the company's expense, at a cost of nearly £1300, but I am glad to say none of these accidents were attended with loss of life.

In one instance, where an inspector found a plain cylindrical boiler working with insufficiency of water, it was impossible to ascertain the actual level of the water, but twenty minutes elapsed before it reached the level of gauge, the pump being in full operation the whole time. At a previous visit of the inspector the boiler was found in a similar condition, and on both occasions the attendant alleged as an excuse that it was impossible to drive the machinery if the water was kept at the proper height. After each visit a report was sent to the assured, pointing out the great danger incurred by this reckless mode of working, and on the second occasion informing him that the company would not hold itself responsible for the consequences, if the practice were persisted in. This had the desired effect, and there has since been no cause of complaint.

Explosions.—The number of explosions and the consequent loss of life in the past year, have been less than in the preceding. In 1863, fifty-one explosions, causing the loss of ninety lives, came under my notice; in 1864 forty-three explosions, with a loss of seventy-four lives.

The following table, though probably not comprising every explosion that has occurred, may be accepted as approximately correct:—

Iron works and foundry boilers	9	causing the loss of	32 lives.
Coal and other mines	9	,, ,,	11 ,,
Locomotive	6	,, ,,	4 ,,
Agricultural engine	1	,, ,,	1 ,,
Steamboat	2	,, ,,	7 ,,
Corn mill	2	,, ,,	6 ,,
Saw mill	2	,, ,,	1 ,,
Flax mill	1	,, ,,	1 ,,
Silk mill	1	,, ,,	1 ,,
Bleach works	1	,, ,,	7 ,,
Chemical works	1	,, ,,	0 ,,
Cement works, flint mill, and brickyard boilers	3	,, ,,	0 ,,
House do.	3	,, ,,	3 ,,
Boilers for other purposes	2	,, ,,	0 ,,
	43		74 lives.

As in previous years, it will be observed that iron-works and mines still retain an unenviable pre-eminence for boiler explosions and destruction of life, but in cotton mills not a single explosion has been recorded for the year 1864.

The total number of explosions that have come under my notice since the formation of this company in the year 1859, is 267, by which 498 lives have been sacrificed. Eight of the boilers which exploded were insured, viz., four plain cylindrical, and four internal-flued boilers. None of the former gave any evidence of defect previous to explosion, but exploded under the ordinary working pressure, without any warning of danger. The plates were not reduced in thickness by corrosion but had evidently deteriorated in quality from the causes already explained under the head of "fractures." Of the internal-flued boilers, in two cases explosion resulted from the same cause, rupture commencing on the underside near the middle, without any previous leakage or corrosion of the plates. The other explosions resulted from defects which could not have escaped detection had the boilers been thoroughly examined. In one of these cases the inspector had seen the boiler only three days previous to the explosion, and being doubtful as to its condition, had then requested an opportunity for thorough examination, which it was arranged should take place within a fortnight, but in the meantime the boiler exploded, in consequence of corrosion induced by leakage. The other explosion took place on the 26th May last, at Messrs. John Davidson and Sons' corn mill, Newcastle-on-Tyne. This boiler, which was made in the year 1856, was 29 feet long by 7 feet diameter, and contained two furnaces 2 ft. 9 in. diameter, connected by means of a combustion chamber with one internal flue, about 3 ft. 2 in. diameter at the back end, but somewhat oval at the junction with the combustion chamber. The latter was strengthened on the upper side by four strong bar stays, with tie rods to the shell, and on the underside by a bar of 3-inch angle-iron, connected also with the shell by means of a plate stay. There was, moreover, a similar plate stay at each side of the chamber.

Leakage having been observed, the boiler was stopped for repairs, and on examination the leakage was found to proceed from the circular seam at the junction of the internal flue and combustion chamber, on the underside. The bottom plate of the latter being considerably corroded, a piece of plate about 2¼ feet long by 8 inches wide was cut out, and a thicker piece substituted. On completion of repairs the boiler was subjected to hydraulic pressure, but not being tight, the seam was again caulked. On the following day the boiler was put to work, and had only been at work a few hours when the flue collapsed at a pressure of about 45 lb. per square inch. On examining the boiler subsequently, I found that fracture had taken place at the circular seam, where it had just been repaired, the old plate having in all probability been strained by the drifting and caulking.

This was evidently the immediate cause of the accident, but not the only defect. On further examination I found that there had been only four rivets through the plate stay and angle-iron on the bottom of the combustion chamber, and these had all been fractured for a considerable length of time. The underside of the chamber may thus be said to have been without any stay whatever, and therefore totally unadapted to so high a pressure as 45 lb. per square inch, the usual working pressure.

The fracture of the rivets was obviously attributable to the unequal expansion of the flue and shell, the evil effects of which have already been referred to. The insecurity of the stay on the underside must have been observed by the men engaged in the repairs, but they appear to have been ignorant of its importance. No opportunity had been given for a thorough examination by the company's inspector, nor was the company made aware of any repairs having been made until after the accident. Had intimation of the repairs been given, the boiler would have been examined, and the accident prevented.

Another explosion, for which the company was liable, occurred on the 22nd March last, at the Denby Iron Works, near Derby. On the 16th February previous, all the boilers at these works had been inspected, and with the exception of leakage at some of the seams over the fires they were found in good condition. These defects were pointed out and repaired.

The boiler which exploded was cylindrical, with hemispherical ends, 40 feet long and 5 feet diameter, made of plates ⅜-inch thick.

It was the third in a range of eight boilers all of the same dimensions, made in the year 1859, and provided with similar mountings. Each had two lever safety-valves 5 inches diameter, loaded to 60 lb. per square inch; two float water-gauges, one of these being connected with the feed valve, and the other with an alarm whistle, to give warning in case of a deficiency of water.

One of Smith's pressure gauges was fixed outside the engine-house for the guidance of the firemen, and another inside for the use of the engineman. Both gauges were attached to the main steam pipe, and would therefore indicate the pressure of all the boilers working. With the exception of a slight discrepancy between these gauges, the mountings appear to have been in perfect order.

The boiler referred to was torn asunder through the line of rivets, at the circular seam of the second plate, about 8 ft. 6 in. from the front end, and divided into two parts. The larger portion, about 31½ feet in length, was projected about 40 yards in a direct line from its original position, without much injury to itself excepting at the end, which was completely shattered by coming in contact with an embankment of slag and other obstructions.

The other portion of the boiler was projected a distance of nearly 100 yards in the contrary direction, striking in its flight a large wrought-iron tube made of ½-inch plates, which it cut in two, carrying a piece of it a considerable distance. This part of the boiler had recently been repaired.

None of the plates gave evidence of deficiency of water; and it is quite certain the explosion was not due to this cause. It was not difficult, however, to ascertain the real cause.

From the appearance of the bottom plate, where rupture had commenced, it was evident that a fracture had existed for some days, probably of no great extent at the first, but gradually extending from rivet-hole to rivet-hole, until not less than 5 feet or one-third of the circumference had become fractured; the primary cause of such fractures, as has been already stated, being the excessive strain to which certain parts of a boiler are subjected in consequence of unequal expansion. The absence of corrosion proved the fracture to have been of recent date, and the evidence of one of the men who examined the boiler internally, about eight days previous to the accident, shows that it must have commenced since that time, or had then been of small extent, and thus escaped notice. There undoubtedly must have been leakage previous to the explosion, but as this fractured seam was beyond the bridge it would be scarcely perceptible from the fire door.

The lap of the bottom plate where ruptured was found to be very brittle and of inferior quality, but the remainder of this plate was very good. This inequality of the iron may be partly attributable to the flame in passing the bridge impinging upon this particular seam, where the overlapping of the plates would render them more liable to injury from overheating. It is worthy of notice that, according to the evidence of one of the firemen, the pressure, which shortly before the accident had been as high as 50 lb. per square inch, had fallen in consequence of fresh fuel having been thrown on all the fires, and did not exceed 47 lb. per square inch when the explosion occurred.

It may seem somewhat incredible that a boiler which had sustained a pressure of 50 lb. a few minutes previous, should be torn asunder in the manner described, when the pressure was reduced; but this is not a solitary instance where such has been the case. Another explosion which I had occasion to investigate in the previous year took place under precisely similar circumstances. Where such a fracture as here described has commenced, if the plate be subjected to tension and the action of the fire, the rent opens and leakage ensues; but this, if observed, which from the position of the fracture is frequently impossible, seldom attracts much notice, being soon stopped by the deposit. Whenever fresh fuel is thrown upon the fire the temperature of the furnace is reduced, causing contraction of the plates. By this alternate expansion and contraction, repeated at short intervals, the fracture gradually extends, imperceptibly reducing the strength of the boiler until a moment arrives when it is no longer able to sustain the ordinary working pressure. This had evidently been the cause of explosion in the present instance.

I may state that the bursting pressure of a boiler of the dimensions above given, and made of good material as this boiler appears to have been, would be not less than 400 lb. per square inch, if subjected to a uniform strain by hydraulic pressure.

This boiler, therefore, being comparatively new, might with good reason have been considered safe to work at 60 lb. pressure; and so far as an opinion can be formed from the evidence given at the inquest, there did not appear to have been any symptom of danger or grounds for apprehension prior to the accident.

The third and last explosion of an insured boiler took place on the 24th June, at the Clarence Iron Works, Middlesbro'-on-Tees. This was also a plain cylindrical boiler, 60 feet long by 5 feet diameter, with hemispherical ends. It was made in the year 1858, and at the time of the accident was working in connection with eight other similar boilers, at a pressure of 32 lb. per square inch. It was heated by gas from blast furnaces, but had also a fire underneath as ordinarily applied to such boilers. About eight days previous to the accident it was stopped for cleaning, and three of the plates over the fire were replaced on account of fractures. Rupture appears to have commenced at the second circular seam from the front end, a little to the right-hand side, through the seam of an old plate, where attached to one of the new ones above referred to. Thence it had extended in an irregular manner, dividing the first 9 or 10 feet of the boiler into several pieces, but otherwise doing comparatively little damage. The hemispherical end was projected upwards, but coming in contact with the large gas tube conveying gas from the blast furnaces, it had rebounded and fallen back upon the right-hand side of the boiler, while the other pieces were found lying on the other side. The remainder of the boiler was moved back upon its seating about 18 inches, breaking the steam and feed pipes. None of the adjoining boilers were injured, and with the exception of two or three men being slightly scalded, no one was hurt.

On examining the plates I found most of them of good quality, but the plate where fracture had commenced, and one or two others, were very brittle. The whole of the plates had in all probability been of good quality originally, but some of those exposed to the direct action of the fire appear to have deteriorated from overheating.

This explosion, which presents another example of the uncertainty of boilers of this construction, can only be attributed to deterioration of the iron, and undue straining of the plates from the causes already explained.

This and many similar explosions lead to the conclusion that longitudinal stays, which have hitherto been deemed unnecessary for boilers of this construction, are essential for their safety.

Another accident, which may be considered an explosion, though very limited in extent, is deserving of special notice, inasmuch as it proves beyond dispute that explosions may, and sometimes do, occur from a cause which hitherto has often been denied.

The boiler to which I refer is cylindrical, with hemispherical ends of ⅜-inch plates, made in the year 1850. It is provided with two 2¼ inch safety valves, weighted to blow off at 40 lb. pressure. On Saturday, the 29th October, a little before 1 p.m. the fireman was suddenly startled by a loud report, and immediately thrown down. At the same instant steam and water issued from the fire door, but being a little to one side, he fortunately escaped injury.

On examining the boiler, I found that about 8 feet beyond the bridge there was a hole in one of the plates, of an irregular triangular form, about 7 inches in length and 4 inches in width at the base. The piece of plate blown out was bent close back against the underside of the boiler, remaining attached at the base for about 1¼ inch long by ½ inch. Around the hole, in the inside, was an accumulation of deposit, extending over an area of about 2¼ square feet, from 1 inch to 1¼ inch thick in the centre, and gradually reduced in thickness towards the outside. In other parts, the boiler was almost free from deposit, but the surface of the plates had a greasy appearance, and at the back end there was a small patch of deposit of the same kind as that just mentioned. The deposit was found to be composed of grease and earthy matters, and ignited like a piece of wood when a match was applied. I can only attribute the presence of grease, either to its introduction by the attendant, which he would not acknowledge, or to its introduction with the feed-water, which at times conveyed grease or soap from some neighbouring soap works. The feed-pipe delivered the water about 15 inches from the centre of the hole in the plate, on the side nearest the fire, and 10 inches from the bottom of the boiler. From inquiry, I ascertained that the feed had been turned on about ten minutes or a quarter of an hour previous to the accident, and the plate itself showed evidence of its cooling effect on that side.

Consideration of all the circumstances relating to this remarkable accident has led me to the conclusion, that after the plate had become red-hot in consequence of the deposit, the latter had become loosened, and fracture taking place, either in consequence of the cooling effect of the feed-water, or from some other cause, water had penetrated the deposit, and intervened between it and the red-hot plate, which must have produced a sudden and excessive generation of steam, sufficient to cause rupture. The quality of the iron was good, otherwise the rupture must have extended, and resulted in a serious explosion. The damage did not, however, extend beyond the single plate referred to, and the brickwork of the side flues. The boiler had been cleaned twelve days previous to the accident, and at that time there was no deposit on this plate, nor any appearance of defect.

Although in this instance the attendant denied having introduced any oil, tallow, or other greasy substance, I have found it a common practice to throw into boilers old cotton waste which had been used for cleaning the bearings of the engines and shafting, under the impression that it facilitated the removal of the scale. The practice is, however, a very objectionable one, inasmuch as the oil combining with impurities in the water, forms a greasy substance, which, when precipitated on the plates, prevents contact of the water, causing overheating of the plates, and at times very serious injury to the boiler. Where exhaust steam from high-pressure engines is used for heating the feed-water, oil and tallow from the cylinders are frequently conveyed along with the water to the boiler, and produce the same results. A simple remedy in such cases is found in the introduction of caustic soda, which, by forming a soap which remains in solution, prevents the precipitation of the greasy deposit upon the plates. This, in combination with surface blowing off, has proved an effectual remedy, where previously the repairs of the boilers were a source of constant annoyance and expense.

The most disastrous explosion which occurred in the course of the year took place on the 17th February, at the Aberaman Iron Works, in South Wales. By this accident thirteen persons lost their lives, and many others were seriously injured. The boilers were not insured, but at the request of the coroner I gave evidence at the inquest. The particulars are as follows.

About half-past three o'clock in the afternoon of the day mentioned, two of the boilers suddenly exploded, spreading destruction in all directions. These boilers were the first and second in a range of seven, five of which were of the same dimensions, viz., 40 feet long by 9 feet diameter, made of $\frac{7}{16}$th plates on the under side, and ⅜-inch plates on the upper side. Each contained an internal flue 3 feet diameter, made of ⅜-inch plates, through which the products of combustion passed on their way to the chimney, after having first traversed the left and then the right-hand side of the boiler. The fire-grate, which was external, was 8 feet square, and about 2¼ feet from the bottom of the boiler.

No. 1 and No. 2 boilers commenced work about the middle of the year 1847, and were therefore more than sixteen years old, during which period they had worked night and day. On the main steam pipe between these boilers was fixed one lever safety-valve 8 inches diameter, and between No. 2 and No. 3 was similarly placed another safety-valve of the same dimensions. Each of the other boilers was provided with a

4-inch safety-valve. All these valves were weighted to blow off at 40 lb. pressure. The other mountings consisted of one float and two gauge-cocks for each boiler, and one pressure-gauge fixed in the engine-house of the blast-engine. Two of the boilers, No. 6 and 7, which were of more recent make, were plain cylindrical boilers 50 feet long by 6½ feet diameter, made of $\frac{7}{16}$th plates. On the day of the accident six of these boilers were working, but owing to a breakage in the mill the mill-engine had been stopped at seven o'clock in the morning, and about an hour before the explosion the blast engine was also stopped to pack the piston. Before stopping the latter, however, the dampers of all the boilers were closed, and the fires "damped;" and according to the evidence of one of the firemen the pressure at the time of the explosion did not exceed 40 lb. per square inch. No. 2 boiler appears to have given way first, and with the exception of about 8 feet of the shell at the firing end, was projected nearly in a direct line over the works, falling about 90 yards from its original position, carrying with it the internal flue, which, separating from the shell in its descent, was thrown some yards further, sustaining little injury.

No. 1 boiler, which was also divided into two portions, had been elevated from its seat to a considerable height, the larger portion falling upon one of the roofs over the puddling furnaces, bringing these to the ground and burying several of the workmen in the ruins. Two-thirds of the internal flue remained attached to this part of the shell, but the other third was projected far up the bank in a contrary direction, and the remainder of the shell, being that at the firing end, was found lying near the stoke-hole of No. 5 boiler. There were no symptoms of collapse in either of the flues, and from the appearance of the plates of both boilers it was evident there had been no deficiency of water; the explosion could not, therefore, be attributable to this cause.

According to the evidence of the manager of the works the explosion of these boilers was not simultaneous, but one immediately followed the other. It is probable, therefore, that on the explosion of No. 2, the violent concussion sustained by No. 1 had been the immediate cause of its explosion.

An examination of the plates removed all doubt as to the cause. The whole surface of the plates below the water-line was corroded in a most remarkable manner, presenting the appearance of honeycomb; and at the seams the plates were so deeply grooved as in many places not to exceed ⅛-inch in thickness, and in some places even less. The rivet-heads had also suffered from the same cause, many of these being entirely destroyed. These effects were most marked in the plates over the fire, and along the left-hand side, where subjected to the most intense heat. Many boilers in Lancashire, supplied with water from the Rochdale canal, or from coal mines, are similarly effected; but I have met with few cases where the corrosion had proceeded so far as in the boilers of which I have been speaking.

From the evidence of one of the witnesses who had charge of these boilers from the year 1845 to the latter part of 1861, they appear not to have suffered from corrosion until about seven years ago, when water from an iron-stone level was allowed to enter the stream which supplies the works with water. The fish in the stream then died, and the water was observed to have a very destructive effect upon iron.

There being little or no deposit on the plates the corrosion could not have escaped notice, indeed, knowledge of the corrosion was admitted. Plates had actually been ordered for the repairs, but those in charge do not appear to have been at all aware of the imminent danger in which the boilers had been working for many months. I can only account for this under the supposition that they, in common with many others, must have entertained the erroneous opinion that however defective a boiler may be from fracture or corrosion on the underside, explosion will never take place provided there be a sufficient supply of water.

After an inqniry which lasted the better part of two days, the jury found a verdict of "accidental death," accompanying it with the remark that "they had no evidence to show that those in charge were responsible for such accident."

In reference to another explosion, by which five persons lost their lives. I may mention that this boiler was formerly insured, but at the expiration of the first year the renewal of the policy was deferred on account of the defective condition of the boiler. In reply to my letter pointing out the defects and the necessity of repairs, the owner informed me that he had had the boiler examined by a boiler-maker from a highly respectable firm, who reported it perfectly safe, and, therefore, unless the company were willing to continue the assurance of the boiler in its actual condition, the policy must lapse. Having full confidence in the company's inspector and the accuracy of his report, I declined to renew the assurance, and the policy was cancelled. The result anticipated followed. An inquest was held, and the usual verdict of "accidental death" recorded.

The last explosion I shall refer to is that of a boiler 20 feet long by 5½ feet diameter, with one internal flue 3 feet diameter, made of ⅜-inch plates. Having been bought second-hand, its age is uncertain. It was not insured, but was examined by one of the officers of the company shortly after the explosion. He found that the flue had collapsed throughout its entire length, and having torn asunder about 6 feet from the larger portion, together with the end plate, had been projected a distance of nearly 100 yards, the shell, with the other portion, taking an opposite direction and alighting about 20 feet from its original position. There was no evidence of deficiency of water, but at the second plate of the flue from the back end there had been an old fracture and leakage, in consequence of which the plate was much reduced in thickness by corrosion. The safety-valve was 4 inches diameter, and in addition to the proper weights the attendant had on the previous day attached a feed-valve mounting and a grate bar, together weighing 60 lb., and giving a pressure on the valve of about 100 lb. per square inch—a pressure more than sufficient to cause collapse of such a flue.

At the inquest no evidence was given as to the actual pressure on the valve, nor did either of the principal witnesses—a consulting engineer and a boiler-maker—make any allusion to the defect in the flue.

The verdict found by the jury was to the effect "that the explosion was caused by the deceased having incautiously put more pressure on the boiler than it could bear." This is only another proof of the danger attending the common practice of attaching extra weights to safety-valve levers of which I have already spoken.

Other examples might be given, but sufficient has, I think, been said to show the necessity of periodical inspection, and the advantages accruing to those who avail themselves of the services rendered by this company.

CONSTRUCTION OF DOCK AND QUAY WALLS WITHOUT COFFERDAMS.

The following abstract of the discussion on Mr. D. Miller's paper on the above subject (which appeared in the two last numbers of this Journal) will be found of interest.

Mr. Miller stated, in reply to questions, that the contract for the pier at Greenock, complete in every respect, 1200 feet in length and 60 feet in width, had been taken for a sum of £63,000, being at the average rate of £157 10*s.* per lineal yard. As yet only about 300 feet in length of the pier had been completed. No difficulty whatever had been found in getting the concrete to set, and to become thoroughly consolidated, even under water 15 feet or 20 feet deep at low-water; and although occasionally there were strong northerly winds and heavy seas in that part of the Clyde, yet the concrete was as solid as rock, and so hard that iron bars would not enter it. Much depended, of course, upon the quality of the materials used in forming the concrete, and upon the mode of preparation. The paper would be found to contain detailed information on this branch of the subject.

Mr. Joseph Mitchell remarked, that the water at Greenock was generally very quiet. From his experience he apprehended that, with rough water, there would be difficulty in getting the concrete to set firm. In some cases he had found that the lime and the sand were washed out by the water, and only the large gravel remained. That appeared to him as likely to arise in depositing concrete in boxes, in the way which had been described.

Mr. Gregory, V.P., observed, that there could be no doubt as to the structural advantages of concrete, if it was allowed to set, and if the materials of which it was composed were not washed away. But concrete generally required a casing to protect it: and while he gave full credit to the author for the ingenuity of the construction of the casing, which carried out the same idea as that which had been adopted in the piers of Westminster Bridge, he feared that, where exposed to a heavy sea, it would be found that there was not sufficient bond between the casing and the body of the work. It was well known that water would often penetrate through the joints of masonry, and whatever might be the precision of the work, he apprehended there would be a risk of the water finding its way behind the casing, and along the line of the bolts, which appeared to be the only means by which the casing was held to the body of the work. He thought that when such a structure was exposed to a heavy sea, damage might from this cause occur to the casing, and incidentally to the whole mass. When using concrete as the hearting of a wall, he had frequently adopted counterforts and bond courses running back from the casing walls, so as to unite them with the mass of the work. It was possible that while in rivers or estuaries, where there was no great run of sea, the system described might, under certain circumstances, be adopted with advantage, it was necessary to pause before using it for walls which required to be well bonded, when they might be exposed to the action of the sea in harbours or breakwaters.

Mr. J. F. Bateman thought the author did not mean it to be supposed that the outer casing was in itself completely water-tight, so as to form a close coffer-dam. He had no doubt that concrete, when properly made, would set as hard as the old red sandstone conglomerate; but there was the risk of the water sucking out the lime before it had become set, and leaving only the gravel behind. In the structure under discussion, there was certainly a want of bond, as had been already pointed out; and he feared that, in a heavy sea, the whole of the veneer-like facing would be stripped off, leaving the rubble backing and the concrete hearting entirely exposed. That, however, would not be of much consequence, if sufficient time had elapsed to enable the hearting to become consolidated, and if the primary difficulty, of preventing the water from sucking out the lime and depriving the concrete of its cementing property, were overcome. If the concrete was of good quality, then the plan described would, no doubt, if successful, ensure a very economical kind of work, and in that view it was deserving of consideration. At the same time, he thought, more experience was required to enable its intrinsic merits to be fairly judged of. It would be necessary, in order to give every chance of success, that the concrete should be composed of excellent hydraulic lime and sharp stones, with little or no sand, so as to possess no particles which could easily be removed, and that the whole of the work should be well bonded together. Although Portland cement, undoubtedly, made the best concrete, where rapid setting was required, a good concrete could be obtained, without the use of cement. For instance, he had frequently employed the Halkin Mountain lime, and the concrete in which it was used set as hard as rock. The character of the concrete depended upon the quality of the lime, and the proper apportionment of the lime to the broken stone or shingle. When lime was used, the concrete would not set so quickly as with Portland cement.

Mr. F. J. Bramwell said, it appeared to be assumed that cast-iron was an improper material to be used in the sea. He should like to know, whether that had been satisfactorily tested in English waters, and also whether the applicability of that material did not depend, very much, upon the quality of the cast-iron; in other words, whether different results had been obtained from using grey or white iron.

Mr. Beardmore fully agreed with the concluding observation of the paper, that everything must have its own special application. With regard to the adaptability of this form of construction to breakwaters, he remarked that the term itself implied a structure requiring such prodigious strength, that it was necessary carefully to consider the circumstances under which that form of construction was to be adopted. He had occasion to inspect the works at the Albert Harbour somewhat critically, and he thought that, regard being had to the local conditions, the plan was well chosen. In the Clyde at Greenock there was but little sea exposure, a heavy sea being in fact very rare. The worst evil that had to be contended with was a rather strong current; but when the first piece of work was finished, a cover was afforded against the current, as far as any washing effect was concerned. The foundation of the pier, generally speaking, was in the very strong "till" usual in that part of Scotland, and was as good a foundation as could be desired; it was situated also advantageously for the excavation of a trench suitable for the reception of the basement bed of concrete. From his examination of the process of manufacture, he considered that both the hydraulic lime and the manufactured concrete were very good. The plan he had found to succeed best, in the manufacture of concrete was, first to make a mortar of lime and sand, and then to mix and incorporate this mortar with the coarser material. With ordinary Thames ballast, for instance, a far superior concrete was made, by first sifting out the sand and blending it into mortar, and afterwards mixing with the remaining coarse material; then by making the concrete at once, by incorporation of the original gravel with the same proportion of lime. The former operation greatly improved the concrete, and economised the use of lime or cement, especially if the ballast and sand were washed before they were used. He had examined the concrete at Greenock at dead low-water, where the surface of lime was being washed by the tide, and it appeared to be perfectly hard and sound. Even with an iron bar, he could not detect anything like softness; in fact, in that situation he doubted whether there would be any wash at all, so as to affect good hydraulic concrete deposited in large masses. This part of the work was well below the level of dead low-water, where the water was comparatively quiescent, and was subject only to the motion within itself. The rise and fall of the tide in the Clyde was very small, and there was scarcely a variation of 2 feet in four or five hours. In some cases, the extent of tide created the necessity for a high vertical wall, so that great strain was thrown upon the work, as at Liverpool, where the difference between the neaps and springs was as much as the whole rise of the tide at Greenock.

If he might give his opinion fairly upon this work—which he presumed was the object of the discussions at the Institution—he certainly looked with suspicion on the want of bond. On this point he would strongly advise the author to be cautious. In the construction of a work like Westminster Bridge, there were two faces tied together, and intimately connected by cross ties; in fact the piers formed a wall with two faces; but in the pier at Greenock there was a mass of material 40 feet in width that might settle between the two walls, and the power that would be exerted on the ties by a small settlement would be very great. Therefore, not only was the strength of the ties important, but also the strength of the grooved iron piles, as they became in fact girders for sustaining the weight of the materials forming the hearting, and for conveying the pressure to the thin facing stones. The solidity of the structure in reality depended on the cast-iron piles, which should be very strong, and on the wrought-iron ties, which should be more numerous than might be deemed strictly necessary by mere theoretical considerations. With regard to the deterioration of iron in sea-water, his own experience did not lead him to anticipate much danger. No doubt, wherever there was sulphuretted hydrogen in the water, there would be a tendency to the decomposition of iron; but such cases were rare, and it was more frequently found that the iron was completely protected by incrustation, particularly when entirely under water. Iron exposed to the tidal wash, and alternately wet and dry, was under another condition; and where it was above half tides it would waste to some extent, unless it was well protected. The chief difficulty in this plan of construction was, that the work was not open to inspection as it progressed. In the old-fashioned system of laying course after course, either by a diver, or from a bell, perfect bond was attained, and everything was seen. There certainly was the apprehension, that the concrete might not set thoroughly solid; but he supposed that in this case the concrete was tried at different depths. It would, however, be necessary to make up for the want of seeing what was going on under water, by giving great extra breadth and strength to the structure.

He thought there was little chance of any settlement in the portion of the work he had seen. A length of between 300 feet and 400 feet was finished, and it looked good, sound work; if there had been any disposition to settle, there would have been some signs of it then. It was a proper application of the plan for the situation, but he should hesitate to adopt it generally. It was to be hoped that there would be an improvement in the mode of carrying out similar large structures, as at present a great heap of spoil had to be run out, unless vertical walls could be adopted; but that must be regulated entirely by the situation, and by the judgment of the engineer in charge of the works. If the proposed plan were generally followed, he would recommend a greater number of ties, so as to afford a substitute for bond; because the plan meant the abandonment of bond, in the old-fashioned sense of that term.

He had used, somewhat extensively, Kentish rag-stone, and also brickwork, as a veneer, with a backing of concrete, formed of ballast and Portland cement, in the proportion of about six to one. He had recently occasion to pull down a wall, built in that manner, about nine years previously, but he found that the work was too strong to be broken up, so that he left the rough concrete remain as the lower part of the wall, and trimmed off a face, and then underpinned several feet in depth with brick piers, with concrete forced in behind. In regard to the use of concrete in large foundations, it ought never to be forgotten, that the heavier and larger the mass put in, the greater was its power of consolidation and chance of absolute and permanent setting into hard rock. When good hydraulic concrete was used in large masses, the general mixture with and surrounding of water was a great aid to the soundness of the work.

Mr. F. W. Shields said, he had known a mass of concrete 9 feet square, when taken up, after having been deposited six or seven months, to be quite soft, although made with the best lime. It hardened, however, almost immediately on exposure to the air. He thought Portland cement was much preferable to Roman cement, and should be used wherever a first-rate concrete was required. He had found ordinary masons' chippings an excellent material for concrete, and superior to gravel alone. When they could be procured in sufficient quantity, and were mixed with gravel and with a due proportion of Portland cement, a very reliable material was obtained. He had put in the foundations of the tall water-towers at the Crystal Palace in that way, with the best results. He quite agreed that the want of bond was a very doubtful feature in the walls constructed upon the plan described in the paper.

Mr. Cockburn Curtis said, the principal thing to be regarded, with reference to the more extended application of the mode of structure advocated in the paper, was the situation in which the works were to be placed, more particularly if proposed to be applied to harbours of refuge. The most important point in the construction of harbours of refuge was the "lead" of sea, and, especially where concrete was concerned, the rise and fall of the tide. He thought it would be sufficient to say that the works under consideration, and which were proposed as a model for others of a larger character, were situated in a place completely land-locked, and between 40 miles and 50 miles from Ailsa Craig, so that the lead of the sea was inconsiderable, not exceeding 3½ miles. The rise and fall of spring tides was only 12 feet, and the difference between spring and neap tides only 8 feet. This showed, to those conversant with the subject, that this form of structure, looking to the want of bond and other particulars previously noticed, could not be applied in exposed situations, such, for instance, as at Alderney.

Mr. W. A. Brooks said, with regard to the form of breakwaters, the author had expressed the opinion, that the vertical wall was the best for resisting the destructive action of the sea, and that it took the least amount of materials. This opinion was entertained by many persons, and appeared to be based on the belief that a deep sea-wave had only an oscillatory movement. He thought that was an erroneous supposition; because it was known that in a gale of wind there was a pressure of from 30 lb. to 40 lb. per square foot, blowing for hours in one direction, and therefore the waves must have a progressive motion. It was found also, that when the wind shifted from one quarter of the compass to another, the sea went down directly. If there were only an oscillatory motion of the waves in deep seas, there would be no occasion for ships to lay to for fear of being pooped.

The piers of the deep-water harbour at Kingstown were constructed with long slopes of 5 to 1, and the cost of the granite used there did not exceed eighteenpence per ton. Those acquainted with quarrying knew, that with a lead of only 2 miles or 3 miles, any rock might be quarried and put into the sea at a shilling per ton. No doubt when the wall could be executed at that cost, breakwaters, or piers, with long slopes, were the best, both as regarded strength and economy. Many millions of money might have been saved to the country, if the engineers of the last twenty years had followed the excellent rules laid down by Smeaton, Telford, and Rennie. In the recent harbour works, it was proposed to build them with vertical walls; but there was no work except the Admiralty pier at Dover, in which that principle was adhered to. At Alderney the pier was a compound of the worst forms. The substructure aided the progressive motion of the waves, while the vertical wall gave them a back sweep, which must in time destroy the rubble foundation and carry away the stones. Nothing could save the superstructure, or vertical wall, but an immense addition to the foreshore, eventually making the Alderney pier a long-slope work. It was stated that the stones on the rockwork slope were converted into boulders, rounded from being tossed up against the facework of the masonry by the action of the waves. That showed a bad system of construction. A great mistake had been committed, in treating certain small harbours in Ireland, as being formed of piers with long slopes, whereas they were not more than 2½ to 1, or 3 to 1. If all had been 5 to 1 or 6 to 1, no objection could have been raised to long slopes. The late Sir W. Cubitt had stated in one of his reports, that he deemed Kingstown Harbour to be the best and cheapest work of the kind in the British dominions, in proportion to its size and extent. That opinion certainly did not favour the system of construction that was now adopted for public harbour works. He had heard with regret that no refuge harbour works for the north-east coast of the kingdom would be assisted by the Government until the public harbours, now in course of construction were finished. Hundreds of lives would therefore be continued to be lost, before anything was done, in places where those works were so greatly needed.

Mr. J. Jennings thought, as the method of construction then under consideration appeared to be greatly dependent upon the iron ties, that the question of their durability was of the utmost importance, as well as the extent to which iron bond might be advantageously made use of in concrete work, and whether in the form of hooping or of rods. When he had cut into work where iron had been used in concrete, he had found the iron decayed to a considerable extent; but, at the same time, a hard metallic compound had been formed round the iron, which might lead to the supposition, that it would not decay throughout its whole thickness. With regard to the manufacture of concrete, recent experiments tended to show, that if made with a much smaller quantity of water than was usually employed, and sufficiently punned, as hard and compact a substance as limestone would be formed in a short period. This of course was a point to be determined by experience. It was said that a labourer could only produce 2 or 3 yards of concrete on that principle in a day; but although such an amount of labour would cause an increase in the cost, yet this would be compensated for by the better quality of the material. He had used Roman cement for concrete twenty years ago, and the result of his experience was, that concrete formed with that cement was very satisfactory, and stood perfectly. The setting of the concrete was as perfect as could be desired, although the tide came over it within a quarter of an hour after it was deposited.

Mr. John Wright said, in reference to the use of concrete in large masses when deposited under water, that some years ago he had built a wall which was 5 feet or 6 feet under water at low tide. That wall had a facing of brickwork 18 inches thick, and the backing was entirely composed of Portland cement concrete. The turn of the tide was exceedingly quick and strong, and it washed over the concrete shortly after it was laid. The concrete he referred to was made of eight parts of Thames ballast mixed with one part of Portland cement, and it was deposited in the water immediately after it was made. It was not mixed by machinery. Three or four years afterwards, when it was requisite to take down a considerable portion of that wall, he had an opportunity of testing the quality of the concrete. It was then found to be as hard as solid rock, so that the removal of the wall was a most difficult operation, and an enormous quantity of gunpowder was consumed in blasting it. Therefore he was sure that well-made concrete was a very suitable material for works of construction, whether under water or not. Where there was not a great depth of water, he had found it an excellent plan, as soon as a face could be established against the water, to force in the concrete at the back, and keep pushing the face on. In this way the concrete at the back did not come in contact with the water, and the surrounding water was not even coloured. When the water was charged with silt, mud or dirt would be deposited upon the concrete, so that the next layer would have a tendency to slide upon it, and would not bind with the mass below, unless the surface was cleaned. As a further illustration of the efficiency of concrete in large masses, Mr. Wright referred to the sea-walls he had built at Brighton. Some parts of those walls were 70 feet in height, and had already stood between twenty and thirty years, without at present giving any indications that they would not endure many years longer. The composition of the concrete in that case was lime and sand, in the proportion of three to one, made into mortar in the usual way, and one barrow load of that mortar was mixed with a barrow load of beach shingle in the pug mill, after which the concrete was immediately pressed into the cases. As the result of his own experience, he felt convinced that concrete was generally made too dry. He believed that it should be used when in a fluid state, so that every particle might settle perfectly and then set, and that the sooner it was deposited after being made the better would be the result. The paper opened a wide field for discussion, as to building under great depths of water. On this subject he should endeavour more fully to express his views upon another occasion.

Mr. J. Brunlees called attention to a design made by him two years ago, at the request of Captain Vetch, R.E., for a breakwater and pier at Point de Galle. It would be seen that that design was almost identical with the system of construction now under consideration.

Mr. Parkes had found great difficulty in ascertaining whether concrete deposited under water, had properly set. Although it might appear hard when tried with iron rods, yet, in some cases, if pieces were brought up out of the water, they were discovered to be soft and "crumbly." He did not mean it to be inferred that he had any doubt that concrete deposited under water might, in the majority of instances, turn out very well, for he had formed foundations in this way entirely to his satisfaction. But he did not think that, at present, the theoretical knowledge of the action of hydraulic limes and cements under water was perfect. It was known, practically, that certain limes and cements would set in water, but not under all circumstances. What were the conditions necessary to insure success did not seem to be fully known. In any particular case, therefore, involving new conditions, there was a possibility of some essential precaution being omitted; and after the concrete had been deposited, it would be uncertain whether it was good, or not. It therefore seemed to him that more than ordinary care was required before such a system as that practised at Greenock could be generally adopted. That such precautions could be taken as would insure success, he had not the least doubt: but these would differ in each particular case. With regard to the section of the pier at Greenock, an objection has been raised, as to the want of bond between the granite face and the concrete. It was in his opinion a fault, that there should be two distinct walls instead of only one to support the superstructure, one for the face and another for the backing, but he did not think that the two could be bonded together—that a concrete backing could be bonded with a granite facing. The concrete would either swell or shrink, and in either case the virtue of the bond would obviously be destroyed. The most natural course to have adopted would have been, instead of making the face-work an integral part of the wall, and allowing the superstructure to bear partially upon it, to have made it a mere shell, so as to protect the surface, and to allow the whole superstructure to rest upon the concrete. If the concrete set well, it would be quite as good as second or third class masonry; if not good, then it ought not to be there at all. It was contrary to first principles, that the superstructure should rest upon two substances so different in their composition as perfectly dressed granite and concrete. The piers of the new Westminster Bridge had been cited as a precedent for this principle of construction; but in that case there was an entirely different feature introduced, as the whole interior of the superstructure of the pier rested upon bearing pies, the concrete merely filling in the spaces between the piles. He believed it was part of the original design to use bearing-piles at Greenock, but that this was afterwards abandoned; and although they were shown on one section (Plate 9, Fig. 3), he understood the work had been executed according to the design shown on the other section, so that the outer edges of the pier rested upon the casing formed of granite slabs, and the interior upon the concrete. No doubt the author would be able to explain why he had adopted a facing of granite of, he believed, 2 feet thick, rather than a shell, which might have been made of cast-iron plates; or even wooden sheet piles would have been sufficient for the purpose, which was only a temporary one, if the concrete were really good.

Mr. MILLER, in reply, said many opinions had been expressed as to the beton, and instances were cited of its setting hard, like solid rock, and requiring blasting afterwards to remove it, while in other cases failure had resulted. He was astonished that so much apprehension should still exist as to this material. He could only account for it by supposing that the compounds in prevalent use for common purposes, and also called concretes, were confounded with the beton, or hydraulic concrete, as applicable to marine construction, and he attributed the failures to the bad materials of which the concrete was composed. The many occasions in which concrete had been successfully employed in works of this description were sufficient to establish its value. Of course in the preparation of beton, certain precautions must be observed. The materials must be properly selected, thoroughly manipulated, and duly proportioned to the work for which the beton was required. If those conditions were attended to, he considered that beton, whether made from the naturally hydraulic limes, or from artificial cements, such as Portland, or even the rich limes rendered hydraulic by the mixture of other substances, such as pozzuolana, would, as certainly as there was such a principle as chemical combination, be successful, and would set like solid rock; and that any cases of failure must have arisen from the want of attention to these principles. Many examples might be adduced of the deposit of hydraulic concrete in sea-water with perfect success; but it was unnecessary to go beyond the Greenock sea pier. The beton used in that work was made from materials obtained within a few miles of the spot, and it had set hard in a short time. It had been doubted whether the whole mass was consolidated throughout; but the answer to that was, that it had been often tested, by means of iron rods, which even shortly after it was put down would not pierce it. It had also been examined by divers, who, when it happened that too much was deposited in one place, preventing the granite blocks from being properly bedded, found great difficulty in picking it away. The best test, however, of the uniform setting of the concrete was to be found in the stability of the walls. It was only natural to expect, if there had been any irregularity in the setting of the beton, that the walls would have shown symptoms of settlement: but nothing of that kind had been noticed. With regard to the observations, as to the danger of depositing concrete in exposed situations, where it was apprehended the action of the waves might, to a certain extent, wash out the lime, leaving only the gravel and stones, he remarked that this would not take place unless the concrete was put down in thin layers, and in that state was allowed to be acted upon by the waves. It should not, however, be employed in that manner, but in large masses, and continuously; and though it was possible that some of the lime might be washed out from the surface, yet this would be replaced by the mass of beton that followed, so that the homogeneousness of the whole mass would not be injured. In illustration he exhibited a specimen of the concrete taken from the most exposed part of the Greenock pier, which had been laid in a soft state, and was afterwards washed by the waves. In point of setting firm nothing more could be desired. That concrete had been put down in a wet state, and was exposed to the action of the waves during the whole of the unusually stormy and severe winter of 1862-3, when several ships were driven from their moorings, in the vicinity of the harbour works, and the large steam dredger was wrecked on the new pier. This specimen showed that the danger to be apprehended from the washing out of the lime was not so great as had been supposed. It had been remarked, that the system of casing adopted at Greenock did not give sufficient bond to the rest of the work. He quite agreed that, in many cases, it might be beneficial to adopt the system of bonding, and in fact it was upon that plan that the pier at Greenock was originally intended to have been built. However the particular style of casing to be adopted would depend upon local circumstances, and upon the individual opinions of different engineers. It was also said that, in any case, the facing could only be looked upon as a veneer, without proper connection with the rest of the work. He could not admit that, because it was efficiently held in position by the iron ties. Besides, he considered that if the concrete set thoroughly, as it would not fail to do if properly made, both it and the casing must together form a solid wall, as much as an ashlar facing did with a backing of rubble masonry in ordinary walls. As to the probable decay of the tie-rods, the great durability of iron when so imbedded was well known. But, whether or not, the tie-rods had only to serve a temporary purpose, inasmuch as when the concrete became consolidated they would not be required. A great deal might no doubt be said for and against any new system of construction; but the best evidence of the plan advocated in the Paper was to be found in the success of the works already completed, and of that success it was open to any one who chose personally to satisfy himself, by paying a visit to Greenock. With regard to the application of the principle to the construction of breakwaters, he considered it had been sufficiently tested to justify the further extension of the plan; and it must be recollected that the Greenock sea pier was essentially a breakwater. In the construction of similar works in more exposed situations, it would only be necessary to make them stronger in proportion, and to take precautions according to the circumstances. There might be danger to the concrete from the action of the waves in a stormy sea; but he proposed to build the work in sections, with cross walls, or casings, at given distances, so that the facing and the beton work would be carried on together, and in that way the concrete would only be exposed to the wash from the surface, which he had shown was not very serious. Breakwaters had been constructed of timber frames filled with loose rubble stones, and these had withstood, successfully, the assaults of the waves. A structure of wrought-iron with a stone casing, even though filled in with only loose rubble, would be much stronger than this; but when in addition the interior mass would be concreted like solid rock, he submitted that such a structure would combine all the conditions required for attaining the greatest stability and durability in the construction of breakwaters.

ARCHITECTURE IN MANCHESTER.

(*Concluded from p.* 161.)

In continuing our notices of the recently built places of worship, several Anglican churches are still necessary to be mentioned; and foremost of these, though only a work in progress, we must place the Cathedral, whose new tower is now in course of re-construction, under the direction of Mr. James Holden. We understand the work, which is now level with the nave roof, will be simply a renewal of the original tower, the main features of which, somewhat uninteresting, and in parts debased, are pretty well-known to architectural students. The stone used is of a very durable kind from the Fletcher Bank quarry, with which the Derby-chapel and other east-end portions of the edifice have been restored. Internally this cathedral is singularly uninteresting; replete as it is with every conceivable modern version of "detestable (if it be detestable) Perpendicular." We only remember with pleasure the choir stalls and ceiling; some fragments of a screen, of what seemed to have been the Lady-chapel; and a painted window in one of the south aisles—the church has several lateral aisles—representing the chief incidents in the history of St. John the Baptist.

In the surrounding suburbs, as Chorlton, Brooklands, Collyhurst, Eccles, and Ardwick, are new churches built and building for the use of the Established Church; but of no marked character one can particularise, albeit there is little to condemn. Mr. Scott is building a fine Early Pointed church at Weaste near Pendleton, with western tower and spire and circular apsidal chancel: the structure is of stone, elaborately moulded; and has a tiled roof, the work is being ably carried out by a Lincolnshire contractor, under all the disadvantages arising from the arbitrary rules of the local trade unions. At Clayton Vale, a fine loftybrick church has been erected from the designs of Mr. Butterfield, having nave and aisles with small tower, chancel with south chantry, gabled transversely, north chancel aisle, and sacristy, with western narthex. The edifice is remarkable for its unusually wide bands of blue brick, tuck-pointed, as is this gentleman's wont, with white mortar; and for the irregularity, apparently purposeless, in the fenestration and spacing of the bays or severies of the church. Still, like all the works of the architect, it is in general outline grandiose and effective.

At Bradford, not very far from this work of Mr. Butterfield's, is a large group of brick buildings, consisting of a church, school, and parsonage, remarkable for the care and skill with which the common brick, used for the meanest purposes in Manchester, has been worked up into an architectural and ecclesiastical form. Christ Church, Bradford, is the very *beau ideal* of a cheap, large church: it is a Decorated church; but, save the mullions and tracery of its windows, and a carved tympanum over the west door, it may be said to be all common brick from foundation to weather-cock; for even the very spire is built of 9-inch brickwork; the bulk of the wall face is composed wholly of the whitey-brown headers of the local red brick; and the general effect is that of an edifice built wholly of London stocks, with sparsely applied red brick bands and voussoirs. Internally the church comprises an aisleless nave, some 45 feet wide in one span, north and south transepts, and a very effective apsidal chancel, with clerestory over a lean-to on each side. The schools and parsonage are designed in harmony with the church, which struck us as better suited to a poor London district, than a poor one near Manchester, as is Bradford. It is a structure worth the attention of the Bishop of London; one certainly possessing an ecclesiastical character of a sort, at a cost which we believe scarcely exceeded three-pence a cubic foot. The schools will accommodate some six hundred children, and have been built at the cost of a private benefactor.

Individual munificence has just now much to do with the building of Anglican churches and schools. In Hulme, another suburb, Mr. Hugh Birley has just founded a large church, capable of holding nearly 900 worshippers. This edifice is also of brick, with blue brick bands and stone dressings. It consists of nave with aisles, the sides of the former lighted by a clerestory with gabled windows, tower and spire in the south-west angle, double south transept and well-developed chancel, from the north wall of which proceeds a cloister, connecting the church with a presbytery; the entire group presenting a striking and picturesque *ensemble*. There is a projecting octangular baptistery on the north side of the church, within which is a handsome carved reredos of Caen stone, considerable mural decoration, and a good painted east window, presented by Miss Birley. The architect is Mr. J. Medland Taylor. The same architect has also erected a church at Brindle Heath, Pendleton, dedicated to St. Anne; mainly at the cost of Mr. Herbert Birley: a small edifice of material before described, having nave, chancel, south aisle, and vestry. In the chancel are constructional sedilia and credence; with painted east window, by Heaton, Butler, and Bayne, of London: subject, "The Good Shepherd." The whole of the sittings are free.

By the munificence of the same gentleman, Mr. Herbert Birley, Mr. Taylor has completely remodelled the church of St. Simon and St. Jude, in Granby-row, introducing a screened-off choir and open seats. St. Stephen's Church, Salford, has been, under the auspices of the same architect, subjected to the like process: the apse contains a most beautiful window designed by the late Welby Pugin. The Church of St. Luke, Chorlton-upon-Medlock, has been rebuilt under the direction of Mr. Lowe, architect; and this gentleman is rebuilding another of the Manchester churches, that of St. Jude, Ancoats. Two other Anglican edifices further bespeak the munificence of the Messrs. Birley—the church of St. Matthias, Saville-street; and the "School Church" of St. Matthew, at Ardwick. The architect, Mr. Medland Taylor, seems to be just now extensively engaged in building churches and schools round Manchester; amongst them, a large stone church at Altrincham, with nave, chancel, aisles, south-west tower and spire. It is capable of holding nearly a thousand sittings.

Not far from this edifice, intended for the poor of the district, is the parish church of Bowden, admirably rebuilt under the direction of Mr. Breakspear, who is just completing a rectory-house in connection with the church; a structure of Runcorn stone, standing within one of the most lovely churchyards in England. The style of the edifice is Perpendicular, the interior marred with painted glass of unsatisfactory character; but the work of the architect is pleasing throughout, manifesting in its varied details great thought and inventive power on the part of its designer.

The Roman Catholics of Manchester have some very fine churches, the chief of course being their magnificent cathedral of St. John the Evangelist, Salford. The external features of this fine edifice are too familiarly known to need mention here; but not every one is acquainted with the interior. The transepts, choir, and chapels, are exceedingly fine; replete as they are with admirable stone carving, "tabernacle work," and painted glass. The churches of St. Wilfrid, by Pugin, the three churches of St. Chad, St. Anne, and St. Mary, by Hadfield and Goldie, are all fine churches, and ornaments to the city; but pretty well-known. The effect of modern street improvements has been to sweep away the old Catholic chapels, and to-day, it may be said, of these churches, there are but two in the city that can be regarded as inferior works of architecture—St. Patrick's, in Angel-meadow, the work of some uneducated builder, and St. Austin's in Granby-row, designed about forty years ago in "the Early English style." Well understood as is that style of architecture in the present day, we should be puzzled to name one other structure in all England, whose architect knew as much of it, forty years ago, as Palmer, the designer of St. Austin's façade, seems to have done. We trust no modern improvements will efface it: it is traditionally recorded of this façade, that the late Welby Pugin, visiting Manchester, observed of it,—"Its designer, whoever he might be, was full a quarter of a century in advance of his fellows in a knowledge of the style he had attempted, though imperfectly, to revive."

Of the three more recently-built churches about Manchester—St. William's, Ancoats, St. Edward's at Rusholme, and St. Anne's at Stretford, the two latter edifices are the work of the son of the last named architect (Mr. Edward Pugin). St. William's church is a plain brick edifice, of less pretension than the two others, which are built of stone, and possess much originality of treatment in their design. St. Anne's, Stretford, is a very fine edifice, erected at the sole cost of Sir Humphrey de Trafford. It consists of a clerestoried nave, borne on an arcade sustained by piers of Purbeck marble; north and south aisles, so narrow, that they would seem to be suited only for processions round the church, a very finely proportioned chancel with octangular apse, sacristies, and an effective tower and spire, somewhat detached from the north-west corner of the church. The edifice is remarkable for its elegant proportions and pleasing details, throughout which, though they are pervaded with an unquestionable odour of originality, and an avoidance of what is quotidian and common-place, it is quite refreshing to see so much, that, without tame copyism, keeps up the sweet semblance of our beautiful English "decorated" work. The structure somewhat resembles Mr. Edward Pugin's published design for the Cathedral of St. Thomas of Canterbury, at Northampton. It is altogether a most successful work.

St. Edward's Church, Rusholme, the other work of this architect, is, like his church at Stretford, an edifice of Yorkshire "pierrepoints," with dressings of Hollington stone. The style of architecture is also English Middle Pointed; the tracery of the windows, particularly of the west window of the nave, indicating an attempt, by no means unsuccessful, at a combination of Geometric and flowing work. The church has a well-proportioned nave, with clerestory, lighted by cinquefoil windows, and separated from its north and south aisles by a moulded arcade, borne, like the Stretford church, on grey marble piers with bases of Sicilian white marble; an octangular apsidal sanctuary, too slightly divided from the nave, a sacristy, and an unfinished tower at the south-west angle of the nave. Over the entrance at the west end is an organ gallery; a feature that we are sorry to see is always to be found in Mr. Edward Pugin's churches. Why is this? The body of the church is fitted up with very well-designed open seats of pitch pine—a beautiful material, quite common in modern Manchester churches, but seldom seen in London. Though a small church, St. Edward's, Rusholme, has much about it that is peculiar and original, the severies of the aisle roofs are not divided, as is usual, by timber trusses, but by internal flying buttresses of plastered brickwork; a novelty whose actual utility is not quite apparent: they appear to have necessitated the undisguised introduction of a row of detestable iron tension rods, a feature which it would really seem some of our new-light Gothic architects are rather proud of than otherwise. We should greatly regret to see the principle of tension—that besetting vice of all modern engineering—invade the construction of our modern churches.

The Dissenting places of worship in and about Manchester deserve a more lengthened description than can be given in this article, the limits of which have nearly run out. Of those built within the last few years, the large Presbyterian Church in Brunswick-street, Oxford-street, claims the first notice. It is a handsome structure of stone, occupying a commanding site at the corner of two streets; the style of architecture is Decorated Gothic, the details somewhat wiry and fanciful. In general outline this is one of the most striking edifices in the city, having a high clerestoried nave with aisles and transepts, a large tower, and lofty spire. A stranger would readily mistake the edifice for an Anglican church, so church-like is the external design. The interior would however dispel the illusion. The architects are Messrs. Clegg and Knowles, of Manchester.

The Independents or Congregationalists have built several new churches in and about the city; one at Rusholme, of which Mr. Alfred Waterhouse is the architect: it is a transeptal edifice of brick, with stone dressings, tower on one side, capped with an effective octangular slated spire, with clock dials. The style is Pointed, and, in general treatment somewhat Lombardic. Behind the church, which is a cleverly designed work, the interior replete with stained and grissaille glass, are situated a group of schools. Mr. Waterhouse is also engaged on another Independent place of worship, nearly complete, at Pin-mill-brow, Ancoats; a brick building, with bands of blue and white brick. In the site of this church, as in the one at Rusholme, the architect has had evident difficulties to encounter, and has met them successfully. The latter building has a tower and spire at the acute junction of two streets. For the same community, Mr. Waterhouse is erecting another church at Whitelands; and Messrs. Paull and Ayliffe, who, by the way, are the architects of a vast general cemetery near Philips'-park, have erected another church at Pendleton. Messrs. Poulton and Woodman have designed several buildings for the same body—schools and churches at Eccles, Chorlton-road, and Stretford. Each of these churches has a tower and spire, and windows filled with stained glass; they are all more or less handsome edifices, bespeaking the munificence of the Congregational dissenters; but in the design of the best of them (the church at Eccles) there is much of the meretricious to complain of.

The Wesleyan Methodists of Manchester have many good chapels (or churches is, perhaps, the most acceptable term,) built here and there with towers and spires, and on an ecclesiastical plan that would have amazed a Wesley or a Whitfield. Messrs. Paull and Ayliffe, the architects before mentioned, have just completed for this body a handsome stone edifice at Levenshulme. Mr. Fuller is the architect of a Wesleyan church at Stretford; a stone edifice, professedly Gothic, consisting of a nave and transepts, with short chancel, and diminutive tower and spire: beneath the whole is a large school, in connexion with the church. We cannot praise the design, which seems composed on the principle of cramming as many features as possible into a small wall-space; a square yard or two of plain wall would be quite a relief to the composition, which is fussy and bizarre to a degree. In the City-road, Hulme, stands another Wesleyan church, of stone, erected under the direction of Messrs. Hayley and Son, architects. This edifice is a Middle-pointed structure, having a galleried nave, or chapel proper, under a wide, high-pitched roof in one span; a semicircular apse for chancel, a small vestry, and well-designed corner tower and broach spire of stone, surmounted by a gilded cross, some 100 feet and upwards from the ground. The internal arrangement of this church is exceedingly ingenious and praiseworthy; particularly in the adaptation of the trussed roof principals to the harmonious introduction of the inevitable gallery, which, as is usual in a Wesleyan chapel, runs round three sides of the edifice.

Messrs. Hayley are the architects of two other Wesleyan churches; one at Rusholme, which may be termed a fashionable outskirt of the city, and another at Openshaw, a district peopled by the manufacturing poor. The former of these two structures is a large Decorated Gothic edifice, of Hollington stone, and pierrepoint or pitch-faced wall-stone; a material that looks better than the Kentish ragstone so common in the metropolis. This church has a wide nave, with gallery at the entrance only, two transepts, and an octangular apsidal chancel with painted windows. Stained glass, indeed, is introduced into every window of the edifice, the interior of which is murally decorated in parts. It is fitted up with an entrance-screen, gallery front, and open sittings of pitch pine, simply varnished.

The chapel at Openshaw, by the same architects, is a brick structure of less pretension, but remarkable for its unusual outline. The general form is that of basilica, with a high clerestory, supported at each side on an arcade, springing from an exposed timber bressummer, borne on two orders of cast-iron piers with parcel-gilt capitals; the lowermost sustaining the timbers of the galleries, whose presence is indicated externally by the double tier of windows in the aisle walls. In front is an open arcade with vestibule, surmounted by a wheel window; and at the rear a plain school, with master's residence.

As has already been said, our notice by no means comprehends all the noteworthy places of worship in and about Manchester: many others deserve mention, but with those raised by the Wesleyan body we break off, and conclude our descriptive sketch of the progress of architecture in and about Manchester.

Railway Breaks.—In a paper on the subject, in *Cosmos*, M. Flammarion calculates that if a common train, going at the rate of 40 kilomètres per hour, or 12 yards per second, were stopped instantaneously, the passengers would experience a concussion equal to that of a body falling from a height of 19 feet; they would be hurled against the sides of the carriage with a force equal to that they would be exposed to in falling from a window on the second-floor of a house. If the train were moving at the rate of 60 kilomètres per hour, they might as well jump from a height of three pair of stairs; and an express train would, in point of fact, make them fall from a fourth story. Instantaneous breaks are, therefore, not to be thought of, and, fortunately, have not been invented; the impetus of a train, even at half-speed, being much too great for any mechanical means of instant stoppage. A break, though instantaneous in stopping wheels, will still leave the train to go forward a little as a projectile, so that there is no fear of any break ever to be invented, perhaps, being too instantaneous in imminent danger. M. Achard, a civil engineer, according to *Galignani*, has invented an electric break, which simply consists in keeping the break or shoes, which lie opposite the wheels, away from them by means of an electric current: as soon as the latter is interrupted, the break falls upon the wheels, and the speed of the train is slackened in consequence. All the engine-driver has to do is to put his hand on a small interrupter, having much the appearance of a door-handle, and this takes him less time than giving the alarm by means of the whistle. Two small Bunsen's elements are employed to produce the current, which are kept in a wooden box.

The Whitehall and Waterloo Pneumatic Railway.—It is said the works of this proposed railway will be commenced immediately on the necessary Parliamentary powers being obtained. The proposed line will commence at an open station to be formed in Great Scotland-yard, and be continued in brickwork under the Thames Embankment to the river; across which it will be carried in a water-tight iron tube, encased in cement concrete, laid and fixed in a channel dredged out of the bed of the river. From the river the line will be continued in brickwork under College-street and Vine-street, to a station convenient for the traffic of the York-road and the Waterloo terminus of the South Western Railway. The steepest gradient will be 1 in 30. The trains will be worked to and fro by pressure and exhaustion alternately, and at intervals of from three to four minutes from each end; a frequency of despatch hitherto unattempted. The carriages will be as commodious, as well-lighted, and as completely fitted for the comfort of the passengers, as those of the Metropolitan Railway. The iron tube will be made by Messrs. Samuda, and the laying of the tube and other works will be undertaken by Messrs. Brassey and Co. The principle upon which the line will be worked will be the same as that adopted on the experimental railway in the grounds of the Crystal Palace. The machinery will be on the Surrey side, at the York-road station. The whole of the works are to be completed in twelve months from the date of the commencement. The cost of the undertaking will be about £130,000. The pneumatic system, by which air is applied to railway propulsion, and the incumbrance of the locomotive is got rid of, differs materially from the former atmospheric system. Under the new system, the train is wholly within a tube or covered way, through which it is rapidly propelled by the pressure of the air behind it, so that not only are all the difficulties attending the continuous valve and the consequent leakage avoided, but the advantage of working with greatly reduced pressures, and with proportionate economy, is obtained. Thus, while the old system necessitated a pressure of from 120 ounces to 160 ounces per square inch to move the train; under the new, a pressure of three ounces or four ounces per square inch is found sufficient. Indeed, in its present form, the pneumatic system is simply an adaptation of the process of sailing to railways; the wind being produced by steam-power, and confined within the limits of a tube.

Excavations in Italy.—Excavations and research increase as well in young Italy as in Rome. On the heights near Torriglia, by the north-east of Genoa, some stupendous and artistically arranged ruins of walls have been laid open, pointing to old Phœnician or Etruscan buildings.—In the garden of the Caffarelli palace, on the Capitol, Rome, interesting ruins of walls have also been opened by the taking down of a recent building. The space opened 10 feet under ground presents a surface of 70 feet. The stupendous blocks of Peperino, similar to those of the Tabularium, and the material of the foundation, point to the ruins of some great public building, and it is most probable that it was the temple of Jupiter Maximus. Hitherto the Roman antiquaries had placed that temple on the opposite or eastern side of the Capitol, occupied now by the Franciscan convent of Araceli, and placed the Arx on the lower level of the Caffarelli palace. If so, the fort could have been commanded by the heights of the temple, which is highly improbable. The excavations at Ostia, the harbour of ancient Rome, are actively pursued by the two Visconti. Lately two fresco paintings have been found, which were in perfect preservation, and were transferred, by a process which is yet a secret, from the stucco on to canvas. The younger Visconti has found a painting which represents the loading of an ancient Roman ship, and above each person the employment he held, is written.

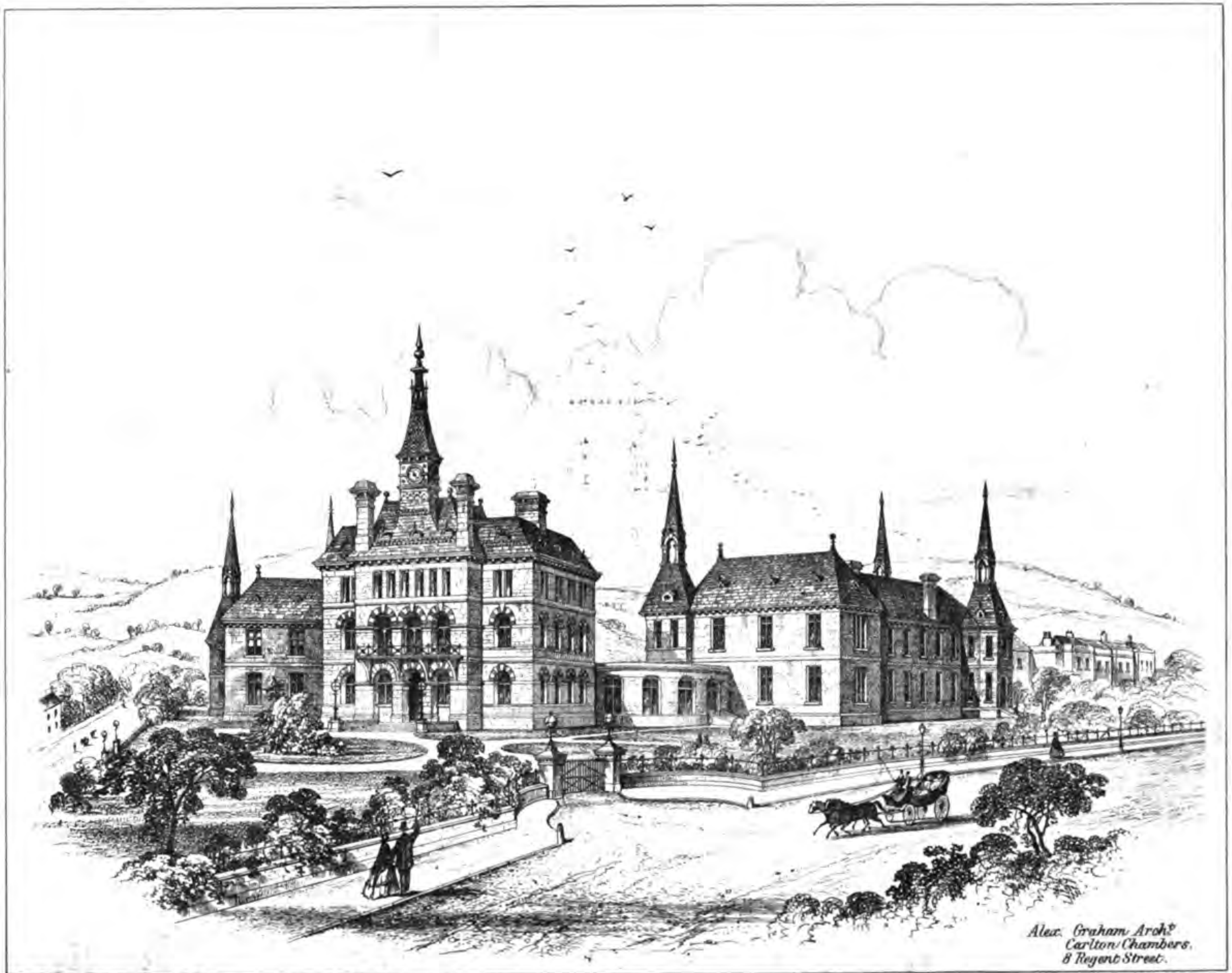
Russian Telegraphs and Railways.—The Russian government have sanctioned the employment of females on telegraphs, as an experiment, to be tried during three years. The persons employed to be between the ages of 18 and 30, and must know the Russian, German, and French languages, besides arithmetic. No married female will be employed, except the husband serves in the same telegraphic line.—Messages from the interior of Siberia arrive in the Continent generally the second day after their delivery, but there have been cases when such messages reached Warsaw or Leopal the same day. The Russian telegraphic lines extend now as far as the Amor, and a diligence runs every month from Kiachta, the Chinese frontier town, to St. Petersburg.

German Photographs of Objects of Art and Industry.—The Imperial Museum of Art and Industry at Vienna, lately established, as well as the Germanic Museum at Nürnberg, are publishing photographs of the principal specimens of the Industrial Department, as well as objects of art. The collection will consist of twelve parts, each containing twelve photographs, and as they will be sold cheap, artists and art-workmen will be much benefitted.—A curious specimen of what may be called a book, has been lately discovered, dating from the latter end of the fourteenth century. Its leaves are of wood, one side of which is covered with wax. This portion contains notes relative to ancient customs, villages, gardens, &c., executed in pen-and-ink drawings of much skill; while on the side covered with wax the stewards of the lord of the manor wrote their official remarks, &c. It seems, therefore, that up to the year 1400, paper and ink were not much used by the German laity.

Italian and Swiss Railways.—The Italian government made proposals some time since that the overland mail (from Alexandria) should be landed at Brindisi, and pass through Italy, Switzerland, and Germany, without touching France. Italy fully appreciates the value of such a change, and every effort will be made to complete the line of railway over the Splügen, and thus effect a communication with the great network of the already existing Swiss railways. The Swiss and German governments have been solicited by the companies interested, to give earnest attention to the project. It is stated that the directors of the combined Swiss lines are ready to carry out the junction between the Splügen and Chur. In other parts of Switzerland, the interests of eight other companies will be involved, and perhaps in collision. The directors of the United Swiss lines are desirous of effecting a junction with the lines of those states on the eastern bank of the Lake of Constance. The Western Company have, by a fusion with the Franco-Swiss and Freiburg-Aarau lines, gained great advantages, and French shareholders now press the government of the Valais for a new connection with the French lines, and for this purpose a new company is ready to complete the Lausanne-Jougne line. In this case the Lyons company would have to connect its line of Dijon with Faugne, whereby the distance from Paris to Milan would be shortened by 44 kilometres. A great improvement will be effected by the Italian line, which from Siera to Brüg would pass on the northern, and from Locarno to Domo d'Ossola on the southern, slope of the Simplon. The central position of Switzerland in the midst of southern and western Europe, and the great traffic upon its railways, have long secured the attention of capitalists. The peculiar formation of the country, however, requires the highest engineering skill.

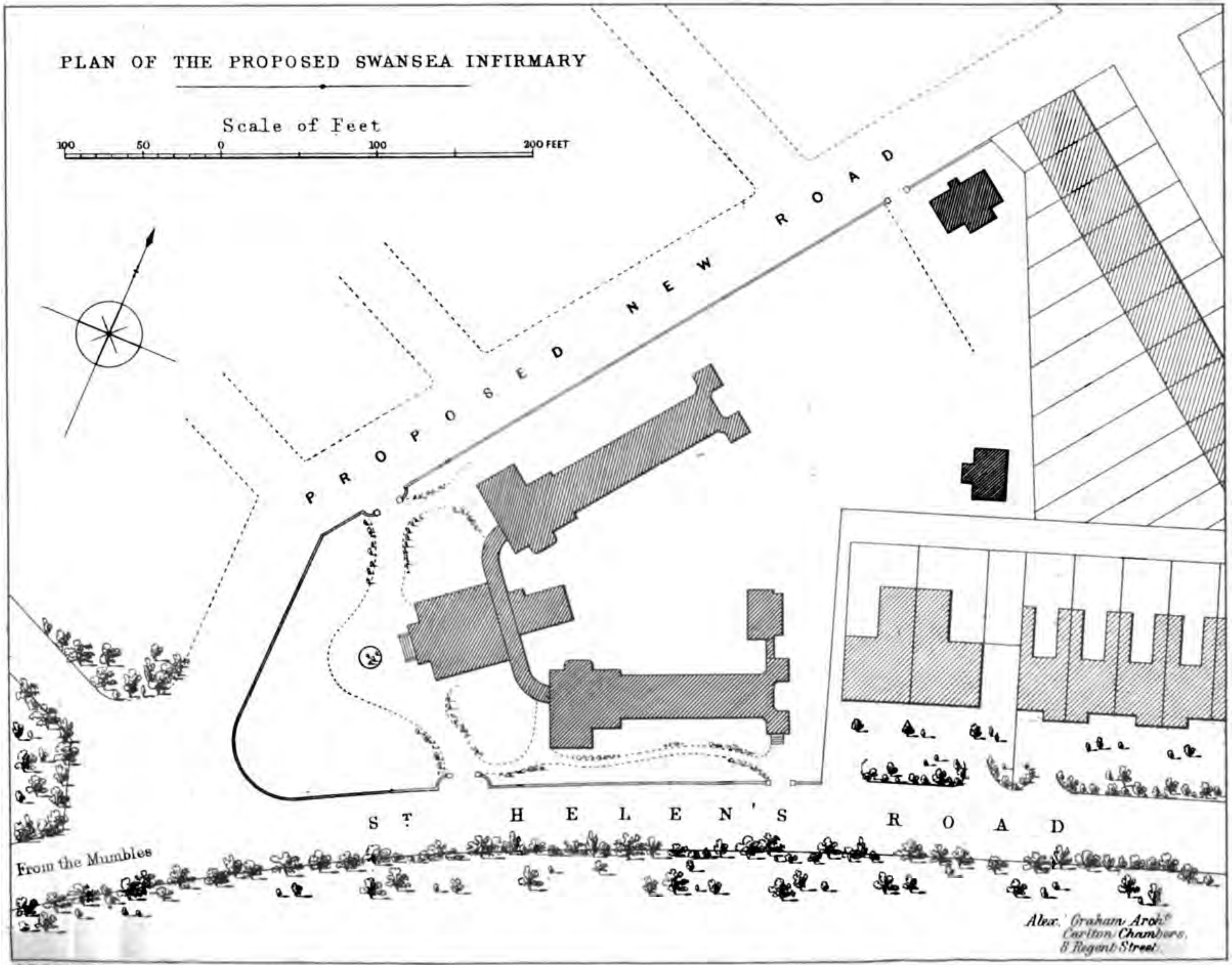
The International Exhibition at Cologne.—Practical Geology, Architectural Materials.—Although no other will ever surpass the great London Exhibition of 1851, yet, after that, the Cologne show claims a high rank. In the department of practical geology, Voigel the architect exhibits a cleverly arranged series of all the stones employed in the building of the Domo of Cologne since 1248 to the present time.—The members of the lodge (Dom-Bau-Hütte) show their art-skill in a number of architectural ornaments, which indicate how far any variety of stone can be used for decorative purposes.—An obelisk 10 to 12 feet high, made of rock salt, is exhibited, from the salt mine near Erfurt, lately opened by the Prussian government. The samples of rock salt from Stassfurt are important to the agriculturist, on account of the salts of potash which they contain. Very rare specimens of salts, as Carnallit, Kieserrit, Sylvin, and Polyhalit, are exhibited here. There is also a basaltic column, 20 feet long, from Linz,—a greater length than any of the Cave of Fingal.—The geological maps hung on the walls, accompanied by numerous specimens of rocks, are most interesting, as well in a scientific as in a practical and commercial point of view. Besides the geological maps of England, that of the Austrian empire deserves notice. It is the result of fifteen years work under the direction of M. de Haidinger. Close to the maps is a collection of rocks and fossils arranged for facilitating the study of the map. A large geological map of Belgium is not only accompanied by specimens of rocks, but there is another interesting map, if we may call it so, showing for what practical uses these mineral substances are employed. There is a great variety of Belgium coal, as well as building marbles, mill-stones, slates, stones for paving, sands, marls, &c. A map of the Rhine lands and Westphalia completes the collection. It is composed of 34 single sections, and its publication extended over ten years. By the liberal assistance of the Prussian Ministry of Commerce, the sections are sold at the price of one thaler (3*s.*), probably the cheapest of geological maps existing.

Pl. 21.



J.R. Jobbins

THE PROPOSED SWANSEA INFIRMARY.


PLAN OF THE PROPOSED SWANSEA INFIRMARY
Scale of Feet
100
50
0
100
200 FEET
PROPOSED NEW ROAD
ST HELEN'S ROAD
From the Mumbles
Alex. Graham Archt.
Carlton Chambers,
8 Regent Street.

J.R.Jobbins.

PROPOSED NEW INFIRMARY, SWANSEA.

(With Engravings.)

Much attention has been given of late years to the subject of hospital construction. The sad experiences of the Crimean war, and the reports and statistics of a Royal Commission, appointed to inquire into the sanitary condition of the military and other hospitals throughout the country and the British possessions abroad, have drawn public attention to the hitherto unstudied laws of sanitary science. Much good has already resulted from these investigations. Defects in existing buildings have been remedied, where practicable. New structures, fulfilling every sanitary condition, have been raised wherever funds have permitted, and a species of emulation has arisen in all parts of the kingdom to provide for the sick poor a degree of comfort and medical relief that had hitherto been confined to the affluent.

We draw the attention of our readers to a work which has recently been selected in competition on its own merits. It has received the warm approval of Miss Nightingale, and other eminent authorities on this subject, on account of its ingenious adaptation to the ground, the simplicity of its internal arrangements, and the admirable distribution of the wards and offices. It may be considered the best 100-bed hospital yet designed.

Swansea, one of the most populous and growing towns in the great iron and smelting district of South Wales, has long felt the want of a good hospital. The present building, erected some forty years ago on the sea beach, for the double purpose of an infirmary and a salt-water bath-house, has latterly been found quite inadequate for the requirements of a very large and increasing working population. To meet the urgent necessities of the district the infirmary committee have given the matter their serious consideration, and, in anticipation of a ready response to their applications for pecuniary assistance from all parts of the country, have already purchased a site of about 2½ acres on the outskirts of the town. The ground is well chosen for the purpose, as it commands a south-west aspect, and being well elevated above the sea receives the soft winds direct from the Bristol Channel.

The new Infirmary, of which we give a view and block plan, will shortly be commenced. It provides for 100 in-patients, of whom 68 are men, and for a large number of out-patients. In connexion with this latter department is a bath-house, the object of the institution (which, we may here mention, is supported entirely by voluntary contributions) being "to afford warm and cold sea-water bathing, and medical and surgical relief to the sick poor from every part of the kingdom."

The building is divided into four distinct departments; the men's wards, the women's wards, the administrative offices, and the out-patients' department, communication being effected by a corridor on the ground floor, and by an open terrace over, affording direct access from the matron's department in the block of building appropriated entirely to administration.

The ward arrangements for males and females are similar in every respect, there being one large and one small ward under the same supervision. The large wards contain twenty-eight beds, the small wards six beds. In the case of the men's wards, the surgical cases, which are very numerous here, will probably be treated in the large wards, the smaller wards being appropriated to medical cases. The dimensions of the large wards are 112 feet by 25 feet, and 16 feet high. The floor space per bed is 100 feet, the cubic space per bed 1600 feet. Between each large and small ward is a nurse's room, with a scullery contiguous. The baths, lavatories, and w. c.'s are situated at the ends of the wards, and are cut off by well-ventilated lobbies. The wards will be warmed by open grates made of fire-tile, placed at a little distance from the wall, so as not to interfere with the symmetrical arrangement of beds and windows. The ventilation will be effected by sash-windows, and inlets for fresh air placed near the ceiling, the foul air being removed by detached shafts carried up in the towers at the ends of the wards. It is the intention of the committee to finish the walls and ceilings of the wards in Parian, or some other hard-setting cement, but this, as well as the employment of any but the ordinary materials in other parts of the work, will depend very much upon the amount of support given to the undertaking.

The kitchen and necessary offices are provided for in the basement of the administrative block, the ground-floor being appropriated for the patients' receiving room, a surgery, and house-surgeon's residential quarters. The first-floor contains the matron's department, including a linen and bedding store, and rooms for house-servants. The upper floor is spaced off into dormitories for day and night nurses, who are kept separate.

There is a small building in the rear of the corridor of communication on the ground-floor, containing an eye-ward for two beds, and a small room for operations. The out-buildings comprise a laundry and a post-mortem room (to be used as a dissecting-room), with a dead-house attached.

The buildings will be constructed of coursed rubble masonry, from the immediate locality, with dressings of Bath-stone. The floors of the wards will be of fire-proof construction, and the windows glazed with plate-glass. Ordinary materials will be employed in other parts of the building. In an early number we shall give the details of the ground-floor and first-floor plans.

The architect is Mr. Alex. Graham, of Carlton Chambers, Regent-street.

IMPROVEMENT OF TOWNS.

By James Lemon, A.I.C.E.

No. II.

(*Continued from p.* 187.)

In continuing this subject, it is the intention of the author to add a few remarks upon the formation of new streets, which he considers of primary importance, and therefore has given the first consideration.

In the previous article the chief object has been to prove the desirability for these improvements, and the beneficial results which have accrued therefrom; also the progress therein which has been made in the metropolis.

In laying out new streets, and in widening existing thoroughfares, the wants of the immediate locality are often only taken into consideration, without looking upon such improvements as a part of the communication of the town taken as a whole: although the ratepayers naturally look upon centralization as opposed to civil rights and privileges, it must be admitted by the most earnest supporters of local self government, that it is only by a central authority that large and sweeping improvements have been successfully carried out. In some of our provincial towns street improvements have been designed and carried out in a much more liberal spirit than in the Metropolis, which, from its large population and rateable value, should set an example to all other cities. It is not to be supposed, however, that the ratepayers of London would bear anything approaching to the enormous taxation imposed upon Paris, amounting to about £3 15*s.* per head; but still, it is hoped that the comparisons which we continually hear between the two capitals, to the disparagement of our own, will infuse into the London ratepayers some little patriotism, and induce them to put their hands into their pockets, and unite in their endeavours to make the streets and buildings worthy of the largest city in Europe.

By means of a very small direct tax upon property within the metropolitan area, a sum of money could be raised sufficiently large to enable the Metropolitan Board of Works to carry out many desirable and necessary improvements, which, from the want of the requisite funds, they are now unable to do.

To meet this difficulty, it is suggested that powers be granted to the Metropolitan Board by Act of Parliament, authorising them to levy a tax of one penny in the pound upon property within their jurisdiction, to be called the Metropolitan Improvement Rate, which would produce about £60,000 per annum; although this is a very small sum, when we consider the work which is to be done, yet, by judicious management, much might be effected which would be of great benefit to the metropolis. According to Mr. Penfold, in his very excellent paper on Metropolitan Improvements, in last month's Journal, the actual net loss on carrying out a new street is equal to one-half or two-thirds of the money expended. There is very little doubt that by purchasing sufficient depth, as before stated, we should, by the sale of the ground rents, reimburse 50 per cent. of the expenditure. With an annual income of £60,000 per annum the board would be enabled to borrow £1,000,000 sterling, if the Commissioners of the Treasury were authorised to guarantee payment of principal and interest, as in the Main Drainage rate; this capital would place the board in a position to do something towards lessening the difference in architectural beauty which now exists between London and Paris.

In treating this branch of the subject, the author must apologise to his provincial readers if he has dwelt too long upon the improvement of the Metropolis, but the object sought is merely the illustration of general principles which the Metropolis, from its being the most known to the majority, best tends to convey.

In designing new streets, particular care should be taken that the traffic is not concentrated upon any one point, as it is evident the chief object sought, viz., improved through communication, is not attained. It is feared by many who have given this subject some consideration, that this error will be perpetrated in the junction at the Mansion House of the proposed new street from the Thames Embankment: this point is already over-crowded, and when the increased traffic, which will necessarily flow down the new street, is added, great confusion must be the result. To obviate a difficulty of this kind, the plan proposed by Mr. Haywood, the City Engineer, to provide for the traffic at the junction of Ludgate-hill with Farringdon-street—viz., the formation of a circus—is an exceedingly good one; or the same thing may be effected by the formation of diagonal streets near the point of junction.

Subways.

The necessity for devising some means of obviating the annoyance to the public by breaking up the streets, and the partial stoppage of the traffic caused by laying gas and water-pipes, has long engaged the attention of the municipal authorities.* As early as April, 1857, the whole subject was referred by the Metropolitan Board of Works to several gentlemen of eminence, to report thereon. The board having advertised for designs for the best mode of constructing subways for receiving those pipes, thirty-nine plans were sent in, and the committee awarded six premiums, viz., for a first-class street—100 guineas for the best design, 50 guineas for the second, and 10 guineas for the third; for a second-class street—50 guineas for the first, 20 guineas for the second, and 5 guineas for the third, The committee, however, stated that they were not satisfied with the detail arrangements of any of the designs.

In the year 1860 the board constructed their first subway in the new street now called Garrick-street, Covent-garden,† which was designed by Mr. Bazalgette, and carried out under his superintendence. They have likewise constructed a similar subway under the new street, Southwark. The cost of a subway of the present section, including side galleries, may be fairly taken as an average at £3 per foot run—the price of course will vary according to the width of the street, as the side passages are increased or diminished thereby. The cost of the vaults under the footway are charged to the leaseholders, or added as an annual charge to the ground rent.

The utility of subways no disinterested person, who is in the habit of passing through the crowded streets of the Metropolis, can question. According to evidence given before the parliamentary committee the number of trenches opened in the undermentioned districts of London, was as follows:—

St. Martin-in-the-Fields	1856 to 1863 inclusive	...	10,377
St. Marylebone ...	1859 to 1863 ,, ...	...	44,932
Strand District	May, 1859 to May 1864 ...	...	9474
St. James', Westminster	1860 to 1864... ...	...	9445
Holborn District ...	1859 to 1863 inclusive	...	5332
Paddington ...	1859-60 to 1863-64 ...	...	9225

As regards the practical difficulties in adapting subways for the storage of gas and water mains, there is considerable difference of opinion amongst the most eminent engineers who have considered the subject. The chief objections which have been raised by the gas and water monopoly of the metropolis are, liability to explosions; want of space for large mains and valves; and cost to the companies in removing their old pipes and relaying them in subways, if constructed in existing streets. The per-centage of air which is required to render gas explosive is stated by Mr. Robert Jones, the engineer to the Commercial Gas Company, at from 800 to 900 per cent. This is generally speaking agreed to by other authorities on the subject. The amount of leakage in gas pipes is stated by Mr. Hawksley and Mr. R. Jones to be from 10 to 25 per cent. This so-called "leakage" is accounted for by Mr. Hawksley as follows. He says it includes the gas burnt upon the company's works, the imperfect registration of meters, over consumption by the public lights, stealage; and, lastly, 5 per cent. only is due to the quantity of gas which exudes from the mains. Then, if 5 per cent. only escapes through the joints from bad workmanship under the present system of laying the mains, it is reasonable to infer that, with more efficient inspection, the escape of gas in subways through pipes laid upon a solid substratum would be reduced to a minimum, and with better ventilation than we have at present there will be really no more danger than now exists in large buildings where there is a large supply.

It is very curious and worthy of notice that in the great controversy as to the employment of subways, the only evidence which was given by a disinterested engineer, viz., that of Mr. Tarbotton, of Nottingham, was in their favour. It is much to be regretted that upon whatever scientific subject evidence is required, there is not the slightest difficulty in obtaining any number of witnesses either for or against; and that gentlemen who are an ornament to their profession should appear as advocates, and not for the purpose of promoting the advancement of science.

The next objection—viz., the want of space for large mains and valves, is merely a question of mechanical arrangement, and one which an ordinary amount of professional skill would easily surmount. If it is contemplated that a 36-inch main or a great number of pipes will be necessary in any street, the subway can be designed to take them: the size is not limited to the area of the existing ones in the two new streets; and for the valves which are required a chamber could be constructed by arrangement with the companies who supply the district.

The total height required for the screw cocks or valves on the 36-inch mains of the New River Company is 8 ft. 10½ in.,* or nearly three times the diameter of the pipe, and the total width 4 ft. 4 in. Not being confined for space there has been no necessity for limiting the height of the gear; but without in any way disparaging the design of these valves, it may be fairly stated that they can be made to occupy less space with equal efficiency; for example, the total height may be reduced to 2½ diameters, there having been large valves constructed upon the Main Drainage works with a total height for valve and gear of less than 2½ times the height of the valve—then why not in subways? The floor of the present subway is 9 ft. 9 in. below the surface of the street; then allowing 18 in. clearance below the valve, we have 8 ft. 6 in. left for valve and gear, which is only 4½ in. less than the height required for the largest valve upon the New River Company's mains. But as the present level of the floor may be lowered in the future subways, there will be ample space for the largest valves required.

Some of the water companies are likewise alarmed at the probability of leakage from the water mains, which their engineers state will flood the subways; but as there is a sewer immediately under the flooring, of greater area than the largest main, into which a number of openings can be easily made, it is difficult to see how such an objection can be maintained.

The cost of laying pipes in subways as compared with the cost of laying the pipes under the present system can only be approximately estimated. It always happens in the adoption of any new mode of working, that there are certain disadvantages under which the workmen labour, until they have acquired a proper knowledge of the subject. The cost of laying the pipes at the present day, although the price of labour is increased, is performed at a less rate than formerly, because the workmen are masters of the routine, and have every facility which modern appliances can give. So it will be in subways: with a tramway in the centre for the transport of the pipes and material, with increased space at the junctions of streets so as to do away with special bends, with increased light and ventilation, and, the most important of all, with the desire to perform the work in the cheapest and most efficient manner; there can be no doubt the cost will not be an impediment to their use.

It is to be hoped that the borough surveyors and others will follow the example which has been set by Mr. Tarbotton at Nottingham, and that the gas and water engineers will unite in the desire to give the system a fair trial. With such a combination of professional skill there can be no question as to the result.

(To be continued.)

* Minutes of Evidence taken before the Select Committee on the Metropolitan Subways Bill, 1864.

† Civil Engineer and Architects Journal. No. 326, Vol. xxiv.

* Mr. James Muir, resident engineer, New River Company.

PATTINGHAM CHURCH, STAFFORDSHIRE.

PATTINGHAM, a retired village, situate a few miles from Wolverhampton, and near the borders of Shropshire, possesses in its church an object of unusual interest. It is a structure which bears evidence of great antiquity, and, like the cathedral church of the diocese at Lichfield, is one of the comparatively few buildings dedicated in honour of St. Chad. For some years it has been undergoing the process of careful restoration and enlargement, under the direction of Mr. Gilbert Scott, and the whole being sufficiently completed, it was duly reopened for divine service on the 25th ult. The plan consisted of nave, chancel, western tower, and south and north aisles; while the order of this enumeration may be taken as a general index to the successive dates of its erection. The most *curious* part of the plan is undoubtedly its quaint little Norman nave; its most *valuable* feature, the grandly simple, but spacious, Early English chancel, the design of which in some respects may be pronounced unique. The position of the tower, too, should be mentioned, as it stands entirely within the church, and is built perfect of itself. This arrangement partly accounts for the shortness of the nave, which is only two bays in length, while the aisles are extended so as to be flush with the west wall of the tower. Upon the Norman pillars and arches on the north side were discovered portions of coloured decoration, chiefly in zigzags, which, however, it was found impossible to preserve. During the restorations, the old doorway leading on to the roodloft was discovered, as may now be seen in its maimed form—one of the nave arches, which is of more recent date, interfering with its full development.

The chancel is both longer and wider than the nave, and of lofty proportions. Its north side is divided into three equal portions by slender buttresses, which are carried up from the ground till they weather under the eaves, without any intermediate set-offs, a bold chamfer, stopped at top and bottom, being substituted for the ordinary square angles. Corresponding buttresses are placed at the N. E. and S. E. angles, and also in the centre of the east wall,—a very peculiar arrangement, and one which necessitates an equally singular fact—viz., two separated windows in the east wall instead of the usual central group. In the present case these windows are ordinary lancets, with very simple details, and precisely similar to those on the north and south sides. In the centre of the east gable above is placed a "vesica piscis," which is quite characteristic of the style. This chancel was the first portion of the restoration attempted, and it was completed a few years ago at the sole expense of the Earl of Dartmouth, who has also been a liberal contributor to the subsequent undertaking. The tower itself is of plain design, and is surmounted by masonry indicating the commencement of a spire, but which, it would seem, was never carried out. The lower stage consists of three open arches within the church, while in the west wall a handsome shafted doorway now replaces a very meagre entrance. The large diagonal buttresses at the angles are carried down within the building, precisely like those outside, and close to one of them stands the primitive-looking font, on a new stone base, in close proximity to the ancient stone book-ledge built in the wall, which has been carefully preserved. It may be mentioned that there exists in an upper stage of the tower a fireplace which bears some indications of antiquity.

The south aisle is of late Decorated character, the east window being a four-light filled with good tracery, while the south and west windows, which had been mostly churchwardenised, are now properly restored. This aisle is considerably wider than either nave or chancel, and the east end has originally served as a chantry chapel: the piscina, &c. still remaining. In the westernmost bay is now added a handsome stone porch. That which till recently stood in place of the old north aisle was of most unworthy design, and badly built. This may now be considered a fortunate circumstance, since there could be no scruple whatever in removing it, and thereby meeting the demands for enlargement as well as restoration. This has been accomplished by the erection of an entirely new aisle, of suitable proportions; beyond which, and separated from it by a handsome arcade, is an additional north aisle, of large area, and with a detached gabled roof. The east end of this extreme north aisle is appropriated as a vestry, being separated from the church by an oak screen of simple yet characteristic design. The new portions have been carried out in the Decorated style, the windows being filled with tracery in various patterns, and the doorways richly moulded.

The piers and arches on the south side of the nave are entirely new, and the clerestory of the nave being of very late design, and in bad condition, was taken down, and has been rebuilt in a more befitting manner, while the debased low roof above has given place to an open one of lofty pitch, covered with tiles, which proves to be, both internally and externally, one of the most successful of the alterations. All the sittings are new, having moulded elbow-ends, and without doors. The aisles have been paved throughout with plain red and black quarries, and an efficient warming apparatus is provided. The pulpit is octagonal, the lower part being of Caen stone, with a central shaft of Derbyshire marble, having a richly moulded cap and base; the upper part is of oak, with shafts at the angles, and each compartment being subdivided by a couple of open traceried arches, springing from detached shafts. An oak lectern is also in preparation, and will stand in the usual position.

The masonry generally has been repaired wherever found defective, and the tower strengthened; the fine set of bells, also, has been under the care of Messrs. Mears, by whom they have been rehung. A new ringing floor has been added; while it is needless to state that the objectionable west gallery has disappeared.

In the carrying out of such extensive works a large outlay has been necessited, but all interested have co-operated freely; the vicar undertaking a memorial aisle at his sole cost, while sundry specific gifts in minor degree have served to enrich as well as to complete the rest. It remains to mention that the whole has been most efficiently performed under various contracts with Messrs. G. and F. Higham, builders, of Wolverhampton, to whom the work was entrusted without competition, and who praiseworthily contrived so to manage matters, that it was not once found requisite entirely to close the church during these multifarious operations.

SOME ACCOUNT OF HENRY DE YEVELEY, ONE OF THE ARCHITECTS OF WESTMINSTER HALL.*

By JOHN GOUGH NICHOLS, F.S.A.

THE biography of English artists in general during the middle ages has been a subject greatly neglected, to the prejudice of our national reputation in comparison with the continent of Europe; and the names and works of our mediæval architects have shared in the common fate.

In the illustrated edition of Walpole's 'Anecdotes of Painting,' &c., 1828, the editor Mr. Dallaway has given (at vol. i. p. 208) brief notices of some half-dozen "eminent master-masons," of the fourteenth and fifteenth centuries, but among them is not to be found the name of Henry de Yeveley. And yet this architect was Master-mason to three successive Kings of England, and to Westminster Abbey; and records are still extant that he was employed in many important works, particularly in the remodelling of the great hall at Westminster during the reign of Richard the Second, and in the erection of that monarch's tomb.

Walpole it may be presumed discredited, or at least he ignored, the statements of an earlier writer, that Henry Yevell built for the King the London charter-house, King's hall at Cambridge, and Queenborough castle; and that he rebuilt St. Stephen's chapel at Westminster. (Constitutions of Freemasony, edited by James Anderson, M.A. 1738.) And in the earlier edition of the same Constitutions (by J. T. Desaguiliers, 1723), Henry Yevele had been mentioned (p. 31) as "the King's Freemason or General Surveyor of his buildings, employed in building several abbeys, and St. Stephen's chapel at Westminster. Preston says he was one of the five deputies appointed by Edward III. to inspect the proceedings of the fraternity of Masons.

Some of these statements are indeed probably guess-work. St. Stephen's chapel was begun about 1330; Queenborough castle is attributed to the celebrated William of Wykeham.

Some slight notice of Yeveley might have found its way into Walpole's work, either from the collection of Rymer, or from the more popular 'Survey of London' by Stowe, where his interment in the church of St. Magnus near London Bridge is mentioned, and he is designated as Freemason to Edward III., Richard II., and Henry IV. Stowe says "his monument remaineth;" but he does not describe it further, nor give the epitaph, of which no copy appears to be extant, the original having probably perished in

* Transactions of the London and Middlesex Archæological Society.

the Great Fire of 1666. Strype, in his edition of Stowe, added a few brief notes from Yeveley's will; and this has now been recovered from the Hustings rolls. The name of Yevele is evidently local, and it was probably derived from the town in Somersetshire now called Yeovil,—this being one of the many ancient forms under which that place appears. But of Yeveley's immediate parentage or family nothing has hitherto been discovered.

Henry de Yeveley, mason, was director of the King's works at Westminster as early as 1365, if not before, and during the 364 days from September 28, anno regni 39, to September 27 in the following year, he received the wages of one shilling a day.* At the same date he supplied 7000 Flanders tiles, for pavements, at 6s. 8d. the 1000, and six mouncells of plaister of Paris at 12s. the mouncell.†

In 1366 the name of Henry de Yeflee occurs as supplying some of the stone required for the works at Rochester castle. Thirteen tons of Stapleton freestone were purchased of him at 8s. a ton; and 32 tons of Thomas Fitzjohn.‡

In 1370 Henry de Yeveley, mason, was employed to retain masons to be sent in the King's retinue over the sea, and was paid the sum of £5 12s. 6d. on that account.§

On the 1st July, 1376, at the requisition of master Henry Yeveley, then tenant of the manor of Langeton in Purbeck, an inspeximus was granted of the record in chancery of the liberties of that manor, as determined by "quo warranto" before the King's justices at Sherbourn in 6 Edw. I.‖ It was doubtless as a merchant in stone that Yeveley had become interested in that locality.

In 1381 master Henry Yevele was employed to engage thirty stone-cutters (latomos) for the King's service.¶ In the same year he designed the south aisle then undertaken to be added to the church of St. Dunstan's in Thames-street, at the expense of Lord John Cobham. The indenture of agreement is still preserved in the British Museum. It was made on the eve of Christmas 5 Ric. II. between that nobleman and Nicholas Typerton mason, and the aisle was to be erected "solom la devyse Mestre Heury Iveleghe," as his name is written upon that occasion,** at the cost of 25 marks. In the same year, at Michaelmas, he had received from Lord Cobham (under the designation of "Masoun et citezein de Loundres") the sum of £20 due to Thomas Wrewk mason for the works at Cowling castle, near the junction of the Thames with the Medway; and by another still more interesting document, dated the 23rd July in the following year, we find that he was employed to measure the work done at the same castle by William Sharnale, which amounted to the cost of £456, of which £270 10s. 4d. was that day paid.††

In 1383-4, by letters patent dated 20 Feb. 7 Rich. II. under the designation of "Henricus Yevele latomus," he was confirmed in the possession of two shops and four shillings yearly rent, in the parish of St. Martin Oteswiche, formerly the property of Master Excestre, and which he had recently purchased of John Totenham, carpenter. This confirmation was considered necessary because he feared that he might easily lose the property through the procurement of certain rivals who had endeavoured to cause it, by false colours, to be seized as an escheat to the crown. The King's favour in the matter was conceded in consideration of the great labours which the said Henry daily sustained in the royal service.‡‡

By an indenture dated 20 April, 7 Rich. II. (1383), between Henry Yevele, citizen and mason of London, of the one part, and William Palmere, citizen and horse-dealer ("merchant des chivaux") of the same city, and Isabella his wife of the other, the former party gave to the latter a yearly rent of 40s. issuing from his lands and tenements in the parish of St. Martin Oteswiche, on condition that if Margaret the wife of Henry should survive her husband, and ask her dower of a tenement with four shops, together with 4s. of quit-rent issuing from the tenements once belonging to John Tudenham, carpenter, which the said William and Isabella held for their lives, of the grant and lease of the said Henry, by the service of 20s. per annum, then the said annuity should be in force, but otherwise void.*

In 11 Rich. II. Master Yevelee was chief mason of the new work then in progress at the church of Westminster, and received for his fee 100s. a year, with 15s. for his dress and furs. Henry Zyevely is also named as chief mason in 17-18 Ric. II.†

At the latter date he was a party to two very remarkable engagements, which are preserved in the collection of Rymer. The one, dated on the 18th March, 18 Ric. II. (1395) is an indenture for making, well and faithfully, all the table of the walls of the Great Hall within the palace of Westminster, on one side and the other: raising them for 2 feet of assise, and inserting twenty-six sousses, or corbels, of Caen stone. The parties to this agreement were the King on one part, and Richard Wasshbourn and John Swalwe, masons, on the other; and the work was to be done according to the purport of a form and model made by the advice of Master Henri Zeveley, and delivered to the said masons by Watkin Waldon his warden. These terms—"selonc le purport d'une fourme et molde faite par conseil de mestre Henri Zeveley," surely raise him to the dignity of an architect, and invest him with the credit of having designed some of the more conspicuous features of Westminster Hall.‡ The same observation may be made with regard to the word "devyse" already quoted from the document relating to St. Dunstan's-in-the-East. In both cases other masons were employed under his direction. The souses, or corbels, in the hall were clearly introduced for the support of the grand roof, which has been so much an object of the admiration of subsequent ages. We have no authority, however, to attribute the merit of the timber work to Yeveley. In the division of labour which was then prevalent,§ it is probably due to the master-carpenter, and the name of Nicholas Walton is found in that capacity.

Another indenture, dated on the 1st April (within a fortnight of the preceding), relates to the "tomb of fine marble" still remaining in Westminster Abbey, which was then undertaken to commemorate the reigning sovereign and his queen, Anne, daughter of the Emperor of Germany, recently deceased. It was made between the King on one part, and Henry Yevele and Stephen Lote, citizens and masons of London, on the other. (This Stephen Lote was afterwards an executor of Yeveley's will.) The tomb was to be made after a pattern remaining with the said masons, under the seal of the Treasurer of England, to occupy in length all the space between the pillars where the said Queen was interred, and to be raised to the same height as the tomb of Ed. III. It was to be finished by the feast of St. Michael in the year 1397, at the price of £250.‖

Yeveley died in 1400; and by his will, dated 25th May, 1 Hen. IV. enrolled in the Court of Hustings at Guildhall, by John Clifford, mason, and Martin Seman, clerk, his executors, he left his body to be buried in the chapel of St. Mary within the church of St. Magnus, where his tomb was then already built. He devised a tenement with houses, shops, &c. on Oyster-gate, in the parish of St. Magnus at London Bridge, purchased 43 Edw. III. of the executors of John Lovekyn, once Mayor of London, and certain tenements with a quay adjoining, called Fish Wharf at the Hole in the aforesaid parish of St. Magnus, purchased 14

* Brayley's Westminster Palace, 1836, p. 196. † Ibid. p. 189.

‡ Fabric roll from 11 June, 40 Edw. III. to 11 Jan. 43 Edw. III. printed in the 'Archæologia Cantiana,' ii 112.

§ Issue Roll of Thomas de Brantingham, Bishop of Exeter, and Treasurer, 44 Edw. III. as edited by Fred. Devon, 1835, p. 3. Yeveley and the workmen are all called "plasterers" by Mr. Devon; but their designation in the original is doubtless "cæmentarii." The "cæmentarius" was a builder in stone; and "lathomus" or "latomus" a stone-carver or cutter: but probably in many cases either term was used for masons without discrimination.

‖ Rot. Pat. 50 Edw. III. m. 18.

¶ Rymer's Collections, Brit. Mus. Harl. MS. 4592.

** Harleian Charters, 48 E. 43: printed in the Account of the Church of St. Dunstan-in-the-East, by the late Rector, the Rev. T. B. Murray, M.A., F.S.A. 1859, small quarto, p. 10.

†† These documents are printed in the Freemasons' Magazine and Masonic Mirror, 1862, new series, vi. 404.

‡‡ "Nos de gracia nostra speciali ad supplicacionem prefati Henrici, consideracione magnorum laborum quos ipse in servicio nostro indies sustinet, statum quem ipse in shopis, &c." The original patent, with the royal seal in white wax, is preserved in the British Museum, Harl. Charters. 43 E. 28.

* From the original among the Harleian Charters, 58 D. 30. The seal has been lost.

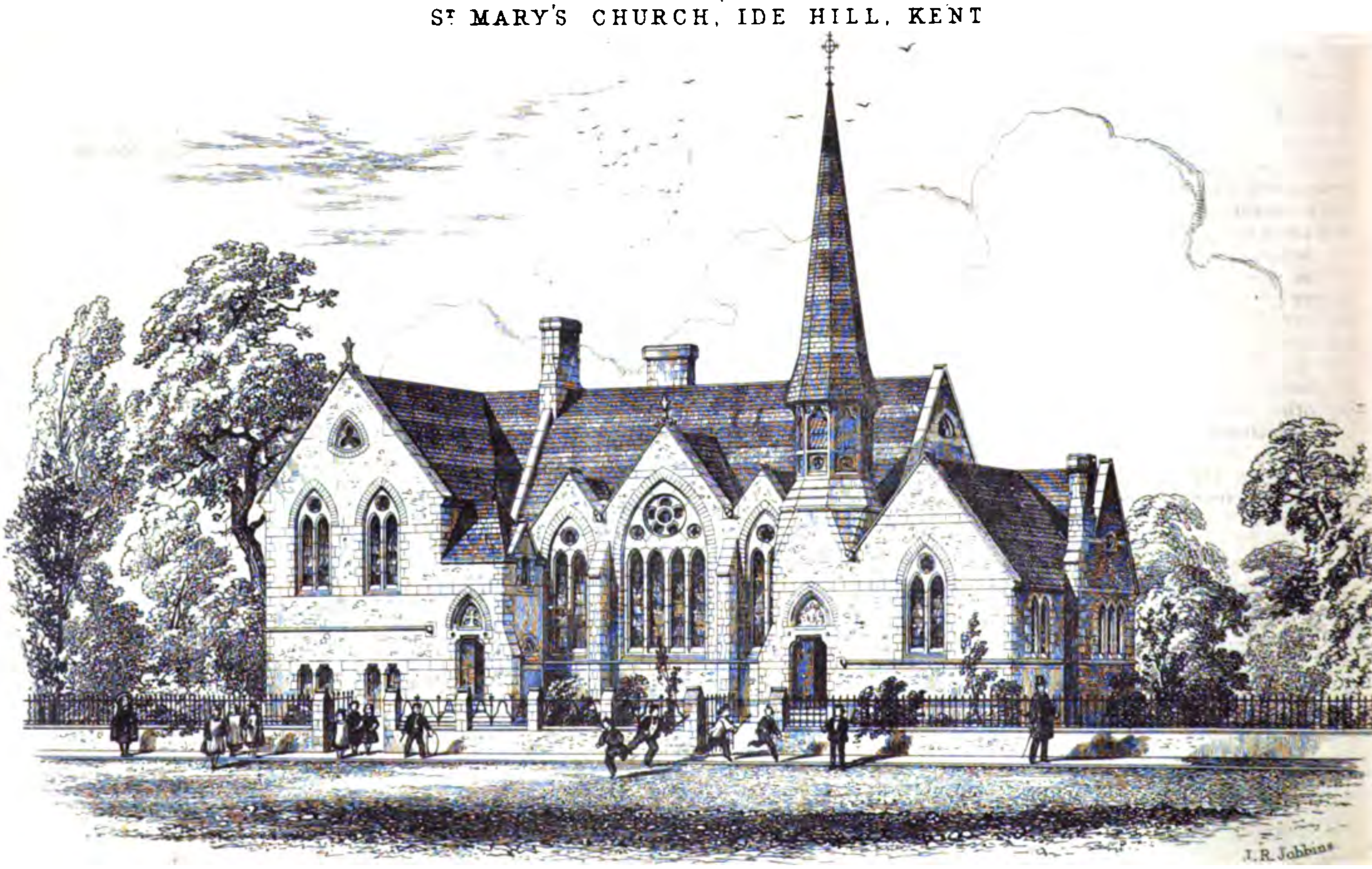
† Fabric Rolls appended to 'Gleanings from Westminster Abbey,' by George Gilbert Scott, R.A., F.S.A. 1861, Appendix, p. 26.

‡ Rymer, Fœdera, &c. vii. 794. The name is there misprinted Zeneley. See an abstract of the same document in Brayley's Westminster Palace, p. 437.

§ Some interesting papers on these subjects by Mr. Wyatt Papworth will be found in the Transactions of the Royal Institute of British Architects; see that on "Superintendents, &c." 1860, Jan. 23, p. 38; and that on "Master Masons," 1861, Dec. 2, p. 37-60; with the Index to both papers.

‖ This indenture is printed in Rymer's collection, vol. vii. p. 795. "Memdum. quod xxviii° die Augusti anno r R. Ric. secundi xviii° dominus Johannes Innocent clericus liberavit in Thesaurariam alteram partem cujusdam indenturæ factæ inter dominum Regem ex una parte et magistros Henricum Yevele et Stephanum Lote latomos ex altera parte, pro una tumba marmorea facienda et reparenda pro Anna nuper Regina Angliæ et pro dicto domino Rege." At the same time agreement was made for the royal effigies, which were to be executed by Nicholas Broker and Geoffry Best copersmyths of London. (Palgrave, Calendars, &c. of the Exchequer, 1836, ii. 50.) Payments to Yeveley and Lote on account of the tomb occur in Devon's Extracts from the Issue Rolls, 1837, pp. 232, 264 On the subject of this monument, and particularly its heraldic devices, see a Memoir by the present writer in the Archæologia, vol. XXIX. pp. 32—59.

ST MARY'S CHURCH, IDE HILL, KENT



HIGHBURY WESLEYAN DAY-SCHOOLS.

JOHN S. QUILTER, ARCHT

Ric. II. of John Horn of Northflete, late citizen and fishmonger of London; and also another tenement with a quay adjoining, annexed to the said Fish Wharf within the Hole aforesaid, on the east part, once belonging to Thomas Osbern son and heir of Gosselin de Clyve, and afterwards to William Polle fishmonger, purchased of John Devene and his fellows 17 Ric. II., and an annual rent of 13*s.* 4*d.* out of a corner tenement, situate upon Oyster-hill, opposite the church of St. Magnus and in the said parish, purchased of John Southcote esq. 21 Ric. II.; all which he devised to Katherine his then wife, for her life, on condition she remained sole and unmarried, and that she should provide two sufficient chaplains to celebrate divine service at the altar of St. Mary in the said church of St. Magnus, during all her life, for his soul, and the souls of his late wife Margaret, Roger and Mariona his father and mother, his brothers and sisters, his lord King Edward the Third, Sir John de Beauchamp knt., John Haket, and all to whom he was in duty bound, and all faithful souls.

And after the decease of said Katherine, or her not keeping sole, nor maintaining such two chaplains, he devised all the said premises to Sir William Frankish, parson or rector of St. Magnus, and his successors, and to Edmund Bolton and Peter Blake, wardens of the fabric of the said church, and their successors for ever, for maintaining two chaplains to celebrate divine service at the said altar of St. Mary, for the souls as aforesaid, and to maintain a lamp perpetually burning, day and night, before the Salutation of the blessed Mary in the aforesaid chapel, and to pay yearly to the parish clerk 12*d.* for keeping and lighting the said lamp when necessary, and to the rector of the said parish 2*s.* yearly, for saying or singing with the said chaplains "placebo" and "dirige, cum nota," and one mass on the testator's anniversary for his soul and the souls aforesaid, and 5*s.* yearly among all the other chaplains of the said church to have his soul and the souls aforesaid in their memory; and to the master clerk of the said church 12*d.* and to his under-clerk 8*d.* to do their offices in due manner as to a year's mind belongs; and for bread or victuals and drink 6*s.* 8*d.* to be spent among the parishioners coming to his "dirige" in the night, and 10*s.* among the poor to pray for the souls aforesaid, and 3*s.* 4*d.* for two new wax candles burning, one to wit at his head and another at his feet, at the time of his anniversary, and afterwards to burn before the image of St. Mary in the said chapel so long as they lasted. And he willed that the said two chaplains should receive at the hands of the said rector and wardens £14 yearly out of the rents of the said tenements, *id est*, each of them £7 for their salary or stipend. And, if it should please the rector and parishioners to charge the chaplains of the church, or their competent assistants, to sing daily a mass of Saint Mary with note or on every Saturday, he desired his said two chaplains might have the appointment, and also to assist in singing nightly the anthem called "Salve Regina," with note,* before the same altar, with saying a colect and "de profundis." The two churchwardens to receive for this service yearly 13*s.* 4*d.* If his tenements, &c. were hereafter let at an advanced rent, the excess was to be placed in a box for their repair. In case of failure of his foundation at St. Magnus, the income to be transferred to the use and maintenance of London Bridge, and to find two chaplains in the Bridge Chapel. He desired that Thomas Hoo his chaplain might be one of the said two chaplains, and that he should not be bound to be present at the said canonical hours, nor other charges aforesaid, except according to his power.

To Katherine his wife, he left for life his tenement called la Glene, in the parish of St. Magnus, and all his tenements in Basynglane and Cordwaner Street, in the parish of St. Martin Otyswiche, provided she kept herself sole, otherwise she to have her dower only; the reversion (when accruing) to be sold, and the money to be distributed for the benefit of his soul and the souls aforesaid, in celebrating masses, distributing to the poor, mending of ways, marriage of poor maids, and other deeds of charity. His wife Katherine to have also for life all his lands, &c., at Wenyngton and Alvythele, or elsewhere, in Essex, with all his store alive and dead; the reversion as before, and specially in aid of the rebuilding of the old isle where the sick poor lie within the church of the hospital of Saint Thomas the Martyr of Southwark; but he wished that Isabella his wife's sister should have for life that mansion in which she lived in the said parish of St. Martin Otyswiche rent free. He appoints as executors his wife Katherine, John Clifford, mason; Stephen Lote, mason; Richard Parker, his cousin; and Martin Seman, clerk; and as overseer, John Warner, alderman.*

* The chantry for singing the anthem "Salve Reg na" every evening in the church of St. Magnus had been founded in 17 Edw III. according to a certificate of which a translated copy is given in Strype's Stowe. Five wax lights were burned at the time of the said anthem in honour and reverence of the Five principal Joys of our Lady aforesaid.

* Hustings Roll, 1 Hen. IV. memb. 3.

ST. MARY'S CHURCH, IDE HILL, KENT.

(*With an Engraving.*)

The parish of Ide Hill, near Sevenoaks, is situated in one of the most picturesque parts of the county of Kent. The originator and and founder of the present church was Bp. Porteous, who, about sixty years ago, erected a small church of the peculiar nondescript character of the period. By the earnest endeavours of the present incumbent, the Rev. A. J. Woodhouse, a large contributor to the fund for erecting this church, ably assisted by the neighbouring gentry and residents, nearly sufficient money has been collected, and the present church commenced. The foundation stone of the building was laid by the Countess Amherst, on the 1st of May last, and the work is now rapidly progressing. The site of the church is 600 feet above the level of the sea, and the structure placed on the top of Ide-hill is a conspicuous object from the whole "Weald of Kent" and surrounding country. The church, illustrated in the accompanying engraving, is of the Geometric or middle-pointed Gothic, and is capable of seating 250 persons. The whole of the work is simple in character, but of sound and good construction, all the carving and other ornamental work being left rough for the present. The east window of the chancel is to be filled with stained glass as a memorial to the good Bishop Porteous. Other windows of a similar character are promised. The architect is Mr. Charles H. Cooke, of John-street, Bedford-row, London; and the contract (£2100) has been taken by Mr. John Kish, of Woolwich.

FIREPROOF MATERIALS AND CONSTRUCTION.†

By T. Hayter Lewis, F.R.I.B.A.

In connection with the use of iron and of the metals generally, in building construction, it may be remarked that the softer ones, as lead and zinc, are of course fit only for covering, and do not enter much into the subject. But in thinking of them for roofing we must remember that zinc melts at a low heat (700°) and then burns fiercely. Lead melts at a somewhat lower temperature (594°). Iron, however, is a great aid now in construction, and its almost universal use suggests the need of most careful research with respect to it. Now undoubtedly it is relied upon by the public as being a safeguard againt fire. Undoubtedly, too, its use is looked upon by the insurance offices as being more dangerous than that of wood. Its first and most obvious defect is its rapidly deteriorating strength when heated, and though the fact is well-known, it is curious that experiments vary very much indeed as to the measure of deterioration. All agree in the fact that at and above red heat (which is common enough in fires) the diminution in strength is great; but below that opinions differ much. Mr. Braidwood's opinion was that iron begins to lose its strength even at such low temperature as 100° and upwards. Mr. Hodgkinson thought that the strength was only slightly diminished at any temperature under 600° (the melting point of cast-iron being 2786°), and was not very much so until red hot, and the experiments made by him and Mr. Fairbairn are by no means clear in their results. It is highly important that the exact facts should be ascertained, because, of course, a low temperature is more common than a high one. My own opinion, from careful observation after every case of consequence, is that wrought-iron is very sensibly weakened, and cast-iron rendered brittle at comparatively low heats; because it is very common to find iron ties and other similar work bent merely by their own weight, in small buildings and other places where the heat has, clearly, from other evidence not been great. The failure of the wrought-iron girders also, drawn from examples at a recent fire, shown on the drawings, tend to the same conclusion, for the whole of them were bent, twisted or broken in the most violent way, although the cast-iron columns on which they rested were only slightly bent. These columns were, however, of much stronger form than is usually found. Anyhow it is quite certain

† Excerpt Proceedings Royal Institute of British Architects. Session 1864-65.

that at higher temperatures, such as are to be expected in a large fire, iron rapidly loses strength, and thus a floor or a beam which would bear the weight upon it quite safely at an ordinary temperature, might break down at a higher one. But I come now to consider of the greater heats constantly produced in our larger fires, and where iron and brass are actually melted. (Specimens of both taken from a recent fire, were exhibited.) The temperature here must have been about 3000°, and the metals retained no strength whatever to sustain even their own weight. Now there can be no doubt that iron offers us most admirable aid with our columns and girders, when used as metals should be; and now that we are getting out of the way of imitating stonework in iron, and that we are using and ornamenting iron as a definite material, undisguised, it is likely to influence, and ought to influence most materially, our designs; and when we call to mind the extraordinary differences produced in its qualities, by such comparatively trifling differences in treatment as those which produce cast-iron, wrought-iron, and steel, annealed and case-hardened iron, we may not be without hope that means may be found of removing the defects which now militate so seriously against its use. Meanwhile we must look upon it as being a most dangerous ally.

Wood is not quite so dangerous a material as is supposed. For instance, I have seen some posts and a girder which remained to the end of the fire which melted the iron and brass within 10 or 12 feet of them. A piece of another post from the same building, and close to the same part of it, where the wood was burnt in to some little distance, and scorched deeply in, yet still retained its strength. Several others remained in the same state, and in ordinary fires, large timbers are seldom burnt right through, but have enough of their substance left to act as struts or girders, though, of course, much weakened. Doubtless, in the case of such extreme heat as the above, there was some current of air which carried the flames away from the wood; but none of the fireman present could say how.

I come next to *concrete*. This is much used for fire-proof floors, and likely to be for many other purposes, as bricks are now getting so very dear. We know well, from the examples of old walling, how valuable a material this is, as we have all seen it remaining quite sound after being used for the hearting of a wall, after its Roman or Mediæval casing has been destroyed for ages. But, so far as my present purpose is concerned, we must accept its use with some reservation. The whole question was entered into very fully by Mr. Tite and others at the Institute in the discussion on Mr. Burnell's paper, and his opinion was that ordinary concrete was not to be trusted. Clearly flintwork is unsafe, as the flint is calcined so much by fire, that walls made of them are shattered to pieces by it. So are the ordinary gravel pebbles, of which here are some specimens. But concrete may be made of broken bricks, as the old Romans made it, and as, I think, Mr. Tite has used it in several cases. I have a high opinion of concrete in fire-proofing, but there have been, nevertheless, cases of some suspicion as to the perfect protection to be derived from its use.

The last substance to which I shall allude in detail is ordinary plaster—perhaps the most valuable auxiliary that we have—as might be expected from its non-conducting properties, proved clearly in the very elaborate experiments made on this subject by Mr. Hutchinson. He tried most building materials carefully, and showed that a combination of lime, sand, plaster of Paris, &c. had less conducting power than any of the others.

I must now consider the combination of these several materials in different forms of construction, and the subject will naturally come under the divisions of walls, piers, columns, or other detached supports, floors, stairs, and roofs. The walls are, of course, the most important, but the least difficult in execution, as brick is at once the best and most common material, for inside work at least. In fact it is, I think, an almost unexampled case for a fire to destroy an ordinary thick wall, as the flames naturally ascend, directing their force on the ceilings, through which they usually find vent; and I have seen fires of great strength stopped even by thin partitions. I saw one case, in the old town of Hamburgh, where a large warehouse was destroyed, but where the fire had not injured the adjoining warehouse, although separated from it by brick nogging only. Sometimes, however, there is such a stop to the flames from a stubborn ceiling or arch, as to allow them no decided vent, and then the walls are exposed to the full action of the fire. Yet even then I have never known good brick walls to fail by being burnt in. There was a great proof of their strength in the case of the vaults of the Tooley-street warehouses, many of which were filled with oil, converted by the flames into a rolling sea of fire, which burnt for weeks. These vaults were built in the usual way of good groined arches, supported on brick piers, and not an arch nor a pier broke down under the trial, nor, after a recent examination of those that still remain, could I see that even a joint had given way. But every portion of the stores over, many of which were built of iron girders on iron columns, presented such a scene of utter ruin that one could scarcely dream of. No one who had ever seen it would place faith again in iron. The greatest damage is to be feared in time of winter, and when the fire is over; then, if one side of a wall has been saturated with water, and the other not so, the water in the open joints freezes, expands, lifts the brickwork on the one side, and bends the wall. I must qualify this opinion as to the sufficiency of brick walls, by saying that the brickwork must be well done; for I have seen cases in which the work was filled in so badly, that smoke poured through the wall at every joint; there was, of course, but little safety there. I, of course, suppose also that the walls are of a fair thickness, but it would lead to too long a controversy to discuss here as to what that thickness should be. I must also qualify what I have above said, with respect to walls of hollow or pierced brick. For various reasons I much doubt the effect of fire upon them, but I have not seen them tried practically, so that I speak upon this part of my subject with hesitation.

Next to the walls come the piers and columns, and these are clearly the most important parts of the building. Their construction is often easy enough on the basement, where space is not usually so much an object; but above that story anything larger than a story post or iron columns is seldom allowed. I have already alluded to the defects of iron, and at present I know of no method of insuring safety in its use. Several means have been suggested. Mr. Hosking tried, in one very extensive warehouse, the plan of putting the columns double in two separate rings, one, in fact, enclosed within the other, his idea being that if one were to break or bend, the other would safely bear the weight. I certainly doubt this much, and in any case the expense is very great, and the size of the columns very much enlarged.

I myself once tried the somewhat contradictory plan of encasing the iron columns with a thick layer of plaster. There is no great difficulty in getting the plaster firmly to adhere, and I think that the plan would be a safer one than that of the double columns. But I am not over sanguine about it, and the system is, at least, liable to the artistic objection, that it conceals the more valuable material of the two. I have already alluded to the plan of sending air through the columns, but there is another plan which has found favour with many, and which provides for filling the columns and girders with water. This at first sight seems plausible enough; but the least thought shows numerous objections. There is, first, the risk of the water freezing, and so bursting the iron—or of the latter expanding, and so letting the water leak at the joints. There must be risk of this, even with ordinary changes of temperature, subject, as these floors must be, to heavy pressure, and still more so in case of fire, when every circumstance is intensified to an extraordinary degree. We must, too, then find the hollows either open to the cistern head or closed securely; if open, the intense heat will convert the water into steam, and blow it out; and if closed, the heat will convert the hollow spaces into so many boilers, charged with steam at a high pressure, without escape valves, and tear the whole to pieces.

But the whole question of supports is intimately connected with that of the floors which they carry. Now I will first take the case of private houses, where there is usually nothing but the ordinary furniture to burn beyond the constructive parts; I assume, of course, that such precautions have been taken as to make the skirtings and partitions solid, because if draughts are llowed through and behind these, the fire will soon be lead through them in spite of every effort. But such precautions having been taken, I see no great difficulty in protecting the house. You may do it as the French do, by iron joists, &c., or in the way used here, and known as Fox and Barrett's plan, or by any way by which the spaces between the iron may safely be filled in with good plaster or other concrete; and doubtless, with long bearings, iron must be used in some way, nor is its use objectionable where such low temperatures only are to be looked for, and when protected by a plastered ceiling. But, in addition to the cost of the iron, it is a material always troublesome to use: one wants to trim a floor, or bevil off a headway, and so on—things done easily enough in wood, but often very difficult or costly with iron; and I really do not see that it possesses any advantage over wood, when the latter is equally protected by plaster and concrete with the iron.

This protection may be had in several ways. We may adopt the ordinary French plan, as described by Mr. Hosking, viz., of having very strong laths, filling in the ceiling from above on to a temporary scaffolding, (instead of pressing it upwards, as with us,) and filling in the whole space between the joists with rubble, so as to form a solid flooring. But this plan has the disadvantage, that the whole weight of the ceiling is carried by the nails of the lathing, and any carelessness or want of skill (not unlikely to be experienced in the use of a method new to our workman) may produce fatal results. With iron joists the laths rest on the flanges, and iron has thus so far an advantage over wood. But I feel quite satisfied that strong, thick pugging would be almost equally efficacious if the sound boards be split in narrow widths, and the soffits plastered so as to form one mass with the pugging over, thus leaving but a very small part of the bottom of the joists exposed. This would be still further protected by the key of the plaster ceiling, if the sound boarding could be brought so low as that the key of the plaster ceiling would unite with that of the pugging. The difficulty in the way is that the fillets must then be brought so low (close to the soffite of the joists) as to render the latter liable to be split and weakened by the fillet nails. An ingenious plan of obviating this was used by Mr. Marrable at the Board of Works offices in Spring-gardens, viz., cutting the joists in a wedge form (two out of one, so as not to waste the timber), so that the concrete filling-in used there had, when dry, all the properties of an arch, and pressed against the joists as its abutment, instead of bearing with its full weight upon the fillets. The floor over being tongued, the draught will be stopped, I fully believe, almost as well as by Hartley's plates. I have recently seen a case of a fire in a warehouse, where the heat was so severe that the wrought-iron doors were bent so as to be useless, and yet the wooden-tongued floor had completely prevented the flames from spreading downwards.

Another way of forming floors has been much used in the Midland counties, and is well known as Dennett's, being formed of concrete, to which I have already favourably alluded. The patentees claim for it greater lightness, solidity, and cheapness than four-and-a-half-inch brick arching, and I fully believe it has them. But the absence of lateral pressure is also claimed; and I cannot at all understand this. If the arch form be of any use, it can certainly only be, so far as I can see, by a pressure on the abutments. If the material itself give the strength, and the abutments are not strained, the floor may be as well laid flat. With good abutments there is much to recommend this plan, as it will, I think, be efficacious, and the arched form worked out of the actual solid, and not by plaster bracketting (as dangerous in case of fire as false in construction) is very much the thing we want, to help us to variety in the section of our ceilings. If, however, the bearings are of iron, Dennett's plan is open to all the objections to which the iron itself is liable. There are also in the South Kensington Museum a great many full-sized models of plans for fire-proof construction, but all, I think, without exception, depend upon iron girders for their bearings or abutments, and such a condition must be fatal to their use. Of another plan, suggested by Alderman Waterlow, where the strength of the floor depends upon a system of iron rods, built into, and therefore protected by the concrete, I speak with reservation, as the system has never yet been tested by an actual fire. But in ordinary houses the heat is so comparatively slight, and the force of the flames so taken off generally by the stairs as an outlet, that there seems to be little difficulty in protecting the floor, whether by this or by other methods. It is in the construction of warehouses and other large places, wherein large masses of combustible matter are stored, that we meet with the really great difficulty, for we have to encounter there an excess of temperature unknown elsewhere. Of all the plans that have been tried for the protection of these places, I suppose that the one of brick arches carried by cast-iron girders is that most commonly used. Doubtless such a floor would be of use in order to prevent fire spreadng downwards. But the iron-lined ceilings as used at Nottingham and elsewhere, where the floors are inflammable, owing to the oil dropping from the machinery, or even an iron-tongued floor, where no such extra risk exists, would go far towards answering the same purpose, whilst what I have already said will show how little dependence can be placed upon the iron if the heat can only get at it. Even if the girders themselves could resist the heat and the water, the arches would at once be deprived of the tie which forms their security, by the bending of the tie rods. For I never remember to have seen a case in which rods, used for whatever purpose, were not found so bent after a fire as to show that their strength as ties are gone. It so happens, too, that the form of the iron girder, often adopted as being the strongest in section, viz., that of the reversed V, is really the weakest in case of fire, as the latter has free access to it in every part, whereas the only chance of a girder being saved is the smallness of its section exposed to the fire.

The system of girders or joists filled in with plaster or concrete is much better than the last, as no tie is required, and, doubtless, in small cases they may be useful. But I have seen them often tested in large fires, and I remember no instance in which they have there formed an effectual stop. (I am now, of course, speaking of warehouses or such buildings, and not private houses.) I may again bring forward the wrought-iron girders shown on the drawings as a case in point, for these formed portions of a floor which had been filled with concrete 18 inches thick. But the ceiling had been formed of boarding only, the soffites of the girders were exposed to the direct action of the fire, and the greater part of the building destroyed. There is, however, always a difficulty in these cases in determining whether the actual cause of the failure was the iron columns, or the girders which they support. For if the columns fail, the bearings of the girders fail also, and the girders must bend or break with the heat and weight. In one remarkable case, where the columns had not been injured, the system had apparently succeeded, the fire having begun on an upper story, and failed at first to work down through the concrete floor. But, some hours after it was supposed to have been subdued, it burst out on the lower story, having apparently sent a stream of heated air through some crack in the concrete, and the whole building was then soon utterly wrecked. This building offered a curious instance in another way of the danger of iron construction. It was circular in plan, the girders radiating to the outer walls from a circular iron framing in the centre. The ironwork got heated, expanded, and so injured the walls that nearly the whole had to be rebuilt, whereas I feel quite satisfied that all would have been saved had the girders been of wood. A curious instance of the danger of iron is given in the drawing of brick arches, being a section of part of a building very much injured by fire some years since. The fire broke out on the story covered with this arched construction assumed to be fireproof. All the arches rested on cast-iron girders, except the arch next to the wall, the girder adjoining which turned out to be of wood, put in either by accident, or perhaps as a piece of scamping work. It is the only case of the sort that I remember. The lower surface was exposed in precisely the same way, and to precisely the same extent as that of each of the iron girders. The fire was one of the fiercest that I ever remember, and burnt into the brick of the wall, directly under the wood, to a depth of nearly an inch, that having been clearly the hottest part. Yet every iron girder broke in half, throwing down the iron arches which they bore, whilst the wooden one remained to the last, with no more injury than its being turned into charcoal for an inch or so in depth. But I must ask you to consider this question as to wood a little further.

If we examine how buildings built of wood give way, we shall find that, as a general rule, they are constructed with long girders of fir, supported on posts or columns, also of fir, connected together only by the thin joists which carry the deal flooring. These latter, unprotected by ceilings, and seldom even by tonguing, are burnt rapidly away, the heavy timbers, thus left without connections to steady them, sway over with their weight, fall into the burning ruins, and add to the fire. Now, if these heavy timbers and posts were of the hard wood which was used of old, and if the space between the joists were filled in solidly with such material as the pugging which Lord Stanhope used, we should have a flooring of much greater value in time of fire than any I know, short of real arches on real brick piers. I do not say that it will be depended upon to stop a fire if once it got a-head. Nothing but arches or piers will do that, unless you divide your warehouses with upright walls, so as to lessen the mass of fire; nor do I contend that there is not a great disadvantage in the use of timber, from its certainty to increase the body of fire if the stairs, for instance fairly ignite, or the floors give way. But I *do* say, that the danger from the risk of sudden failure in the iron more than counterbalances this; and that if stairs, and floors, and columns were made as I have alluded to, they would offer such chances of delay as might be of the utmost use in preventing loss; and I know well that the men in the brigade would feel themselves secure with such construction, and fearlessly work to save it; whereas even Captain Shaw himself would hesitate to lead, or the most daring of his men to follow him into a building, when they knew that the lives of all within it depended upon a frame of iron.

I must offer a few words as to *roofs*. The objections that I have elsewhere offered to the use of iron do not apply here, and it is probably the best material to be used. But I must venture to give a caution that battens must be used in the covering, and not boarding, as the fire runs along the latter with great rapidity. I must also notice another practical point recently brought under my notice by Captain Shaw, and which had quite escaped me, viz., that when cisterns are provided against the risk of fire, they should be at a considerable height, as it takes a pressure of 15 ft. of water to open the firemen's hose.

I now come to the last part of my subject, and perhaps the most important of any, viz., the stairs. The example I have selected is one of melancholy interest, as it was connected with the deaths of three persons; but the construction of the staircase was of so uncommon a character, as to make it an unusually good case to which to refer. It had walls on three ides, but on the fourth only a thick quarter partition, not brick-nogged, but lathed and plastered as usual. The steps were of good sound Portland, with one end pinned well into the side of the wall, and secured into the wooden partition by strong cross pieces of wood framed with the uprights. The landings were formed of wooden joists, with plaster ceilings. The fire broke out in the basement story, and could have been of no very great intensity, as the ceiling over was not at all burnt through, and all that there was to feed the fire was the kitchen floor, fittings, and one cross partition. It passed through the door on to the stairs, swept up the stairs, was stopped by a lath and plaster ceiling at top, and rushed out by a window close under it. All the doors of the various rooms leading on to the stairs were shut, so that no damage was done to any of the rooms except by smoke and water. Now this is a good illustration of the effect of the first sudden burst of flame, for there was nothing to burn or add to the fire on the staircase, and the only heat was from the rush of flame. Yet before any of the engines began to play the staircase broke down from the top, and crashed down the whole underneath, leaving the ends projecting from the walls and wooden partitions, which latter held the stair-ends as firmly as the walls did. I was, at first, quite puzzled to account for this. At length I found that a large cistern was on the upper story, full charged at the time of the fire—that a hole had been burnt through the service pipe from it, directly over the top steps, upon which, thereupon, the whole weight of cold water had come down suddenly, in their heated state. These had snapped off, and broken the rest (rendered brittle by heat) in falling. I have since seen another stone staircase, of similar construction, broken down from apparently the same cause, and others would, of course, follow in the same way directly the engines played upon them. But the fact to which I wish to draw your attention more particularly is that the only parts of the whole staircase which remained secure were the wooden landings, protected only by the plaster ceilings; and that while every part of the fire-proof construction was utterly destroyed, I took my observations in complete security on these said landings, which remained to the last uninjured.

As a practical result I may, however, say generally, that if the stairs be supported at each end, as they were in the old geometrical and other staircases, it matters very little what their construction may be, as they would be pretty safe any way. For you will find that the way in which a staircase of stone is destroyed, is by the fire rushing up the central well-hole, and heating the outer ends to excess. The steps thus become excessively brittle, and snap off at once whenever any sudden weight or change of temperature is brought upon them. With wooden stairs the case is different; they are seldom set fire to from underneath, as the plaster ceilings invariably protect them, unless the plastering is very bad. But the outer string, exposed to the full force of the flame, catches fire; the flame spreads thence to the riser and the tread, gets thus *behind* the plastering, and the stairs are then destroyed. The present fashion of cut string is a wonderful help to fire, as it gets at once, without a step, from the outer string to the treads and risers, and it would be no slight step towards safety if the present fashion were discarded in favour of the old massive solid strings and newels. If these were re-used, and the stairs made solid with plaster, on some plan like the French, there can be no question whatever that wooden stairs would be something very nearly fireproof. I ought to refer here to one fine example of a different construction—that of old Rochester castle—the old staircases whereof are formed of concrete, bedded on wooden templates, the marks of which remain now as perfect as the day on which they were laid; and I believe that these old stairs would resist now the trial of fire, as they have that of time and weather for some five centuries.

HIGHBURY WESLEYAN DAY SCHOOLS.

(With an Engraving.)

These schools are situated in Morland-terrace, Holloway-road, occupying a site of land adjoining the Wesleyan Chapel, with which they form a very striking and picturesque feature. The style of the building is made to harmonise with the chapel, the walls being faced with Kentish rag, with Bath-stone dressings. The boys' school, which occupies the centre, is 30 ft. by 48 ft., with two large class-rooms. At the east end is the infant school, with the girls' school above, each 58 ft. by 20 ft., with a large class-room to each. Each school has a good-sized open playground, with covered play-ground beneath the boys' school and class-rooms. The entrances to all the schools are distinct, that to the boys' being surmounted by a belfry and spire. The schools have been arranged to accommodate 500 children. The contract has been taken by Mr. Henshaw, of City-road Basin, London. The schools are now in course of erection from the designs and under the superintendence of Mr. John S. Quilter, architect, West Brompton, London.

ARCHITECTS' CHARGES IN CANADA.

The following professional charges were agreed upon and signed by twenty-five architects in February last, and are now generally adopted in Montreal:—

	Per Cent.
1. Public buildings and private residences, commission on the cost thereof of ...	5
2. Block of two houses of similar design, commission on the cost thereof of ...	4
3. Block of three, four, or five houses of similar design, commission on the cost thereof of ...	3
4. Block of six or more houses of similar design, commission on the cost thereof of ...	2½
5. Stores and warehouses, commission on the cost thereof of ...	4
6. Block of two stores or warehouses of similar design, commission on the cost thereof of ...	3
7. Block of three or more stores or warehouses of similar design, commission on the cost thereof of ...	2½
8. Items of charge comprised in 5 per cent. commission: preliminary sketches, working drawings, and specifications sufficient for an estimate and contract ...	2½
Detailed drawings ...	1
General superintendence (exclusive of clerk of the works), examining and passing the accounts (exclusive of measuring and making out extras and omissions) ...	1½
9. N.B.—The foregoing subdivision of charges to apply proportionately to stores and warehouses, &c.	
10. For works in the alteration of premises the remuneration to be increased according to the time, skill, and trouble involved.	
11. Taking out quantities from plans for a detailed estimate, commission on the amount thereof of ...	1½
12. Measuring and valuing artificers' work done for any amount under $1000 ...	2
Over $1000, and under $4000 ...	1½
Over $4000 ...	1¼
13. For services by time at per day ...	$10
14. N.B.—All travelling expenses to be charged extra.	
15. No charge to be made for a rough estimate obtained by cubing out the contents. If a detailed estimate be requested by the proprietor, a charge therefore is to be made as above.	
16. An architect is bound under the full per-centage charge to provide one set of drawings and one set of tracings with duplicate specifications; it being understood that the architect is paid for the use only of the drawings and specifications, and that these, in the event of his carrying out the works to completion, are to remain his property.	

ON THE MEANS ADOPTED IN THE FACTORIES AT LOWELL, MASSACHUSETTS, FOR EXTINGUISHING FIRE.*

By James B. Francis.

The first cotton mill at Lowell went into operation in the year 1823; it was provided with force-pumps which supplied a cistern in the roof and a hydrant in each story. There were no hydrants outside of the building. All the cotton mills erected in Lowell previous to the year 1828 were protected in the same manner. In January of that year a mill was burned down, and the want of some more efficient means for extinguishing fire was clearly shown. The plan was then adopted of laying an eight-inch main pipe through each mill yard, about forty feet in front of the mills; this pipe was furnished with hydrants, and was connected with the force pumps and roof cisterns of each mill, so that all the apparatus on the premises could be brought to bear on any one mill. When the force pumps were not in operation, the supply and pressure of water in the mains depended entirely on the cisterns, but by means of a peculiar system of valves at the cisterns, a pressure equal to a head of one hundred and fifty feet, could be maintained in the main pipes when the force pumps were in operation.

The next improvement of importance was made in the years 1847 and 1848, when the main pipes in the several mill yards were connected, so that, as far as the capacity of the eight-inch main pipes would permit, the force-pumps in all the mills in the city could be brought to bear on any one mill. In 1859, a reservoir was constructed on an elevation about a mile from the nearest mill, and connected with the main pipes in the mill yards by means of a twelve-inch pipe, through which the water passes, either from the mill yard mains to the reservoir, or the reverse, according to circumstances. When full, this reservoir contains about two millions of gallons, and gives a head in the main pipes in the mill yards of from one hundred and eighty to two hundred feet. The supply of water in the reservoir is maintained by means of force-pumps, erected for the purpose, driven by water power. It was originally designed to limit the use of this water to the purpose of extinguishing fires; the high and constant pressure afforded, however, great advantages for supplying the steam boilers used for heating purposes in the mills. Water is drawn from the mains in most of the mill yards for this purpose. About a dozen dwelling-houses are also supplied, and small quantities are occasionally drawn for building and other purposes. The whole quantity drawn for other than fire purposes is, however, too small sensibly to affect the pressure in the pipes. The city having no public water-works, urgent applications have been made for the privilege of tapping the pipes, but they are jealously guarded, as the efficiency of the whole system depends in a great degree upon maintaining a constant high pressure in the mains, which the experience of other cities shows can scarcely be done, if the water is generally used for domestic purposes.

Previous to the year 1850, the large manufacturing corporations at Lowell had seldom effected any insurance on their property against losses by fire, but had relied upon laying aside a portion of their earnings, as an insurance fund, to meet such losses as might occur. An efficient system of watching had been adopted from the first, and great care was constantly exercised in guarding against fire, and in keeping up the apparatus for extinguishing it. In the year 1850, they entered into an agreement for mutual insurance; some modifications indicated by experience have subsequently been made in it; as now in force it imposes very little restraint upon the manufacturing operations, and provides for the distribution of all losses among the co-insurers, in proportion to the irrespective capital stocks. Nothing however is paid on losses of less amount than one thousand dollars, and no member is obliged to contribute more than two per cent. of its capital stock on account of any one loss.

The aggregate amount of the capital stocks of the co-insurers is $13,600,000, and the amount of loss by any one fire covered by the mutual insurance is $272,000. Only the property within the limits of the mill yards is covered by the mutual insurance; no exact estimate of its aggregate value has ever been made, but when the usual stocks of materials and goods are on hand it is supposed to be equal in value to about three-quarters of the capital stocks, or $10,200,000. The whole number of losses covered by the mutual insurance during the fourteen years and ten months since its adoption, ending April 14th, 1865, was fifteen, amounting to $141,818·32; the average annual loss being $9,560·79. If the value of the property insured is taken as above stated, the average annual loss has been a little less than one-tenth of one per cent.

The mutual insurance agreement provides a mode for ascertaining the amounts of losses, and also, for frequent inspections of the apparatus for extinguishing fire, and for the ejection and withdrawal of any of its members. Since this arrangement was entered into, there has been much interest felt in perfecting the apparatus, and great expense incurred in so doing. The lines of pipes through the mill yards and the connections from one yard to another, made an irregular line of eight-inch pipe, about three miles in length, having a general horse-shoe form; the connexion of this line with the reservoir was at one point, near the toe of the shoe; in 1853, an important improvement was effected, by connecting the ends of the horse-shoe lines, by a pipe of the same size, about three-quarters of a mile in length. Since this connexion has been made, the water drawn in any mill yard from the reservoir, passes through the 12-inch pipe to the 8-inch pipe, thence through both branches of the 8-inch pipe, to the place of delivery, or a point near the same. In each mill yard there are several sets of force pumps, driven by water-power, these are kept ready for immediate use; the water thrown by them is discharged directly into the 8-inch main pipe, and any excess of water not drawn from the main passes up to the reservoir.

Each mill yard is supplied with numerous hydrants; on an average one to about every fifty feet in length of the main pipe at the front of the mills, and nearly as many at the rear; about one-third of these hydrants have one hundred feet of hose and a hose-pipe constantly attached; these are protected from the weather by small buildings, in which the hose is hung ready for instant use. Supplies of hose are kept at hand for use at the other hydrants, and ladders with platforms at each story are fixed at several places on the sides and ends of the buildings; these serve for fire escapes for the operatives, as well as for purposes connected with extinguishing fire. Lines of pipes about four inches in diameter are carried from the mains into the mills, passing up to the top, and having a hydrant at each story, with hose and pipe constantly attached. As a rule, there is such a line at each stairway, the pipe and hydrant being placed in the rooms, as near as practicable to the head of the stairs. This situation is preferred, as it enables the operators of the apparatus, to remain longer at their posts, and with more sense of security, than they could do at points from which escape would be less easy and certain. The mills built previously to 1845 were generally about 156 feet long, 45 feet wide, and four stories high, besides basement and attic; these mills have usually one stairway, placed in a projection or porch in the middle of the front. Mills of later construction are generally larger, and have two or more stairways, and a corresponding number of lines of pipes and hydrants. These pipes are constantly filled with water under high pressure, and the hydrants are kept ready for instant use.

It has been found by experiment that in one of the mill yards, least favourably situated, four of the hydrants outside of the mills, discharging through three-quarter inch nozzles, could be supplied at one time, and throw water to a vertical height of about seventy-five feet above the nozzles; when the number was increased to eight the vertical height to which the water could be thrown was reduced to sixty feet. In this experiment none of the force pumps were in operation, the entire supply being drawn from the reservoir. In some cases, when the force pumps in several mills were in operation, twenty-five or more hydrants have been effectively used at once. In case of fire, the nearest apparatus is got into use as soon as possible, and if there is any probability that a larger quantity of water will be wanted than can be supplied under a suitable pressure from the reservoir, the force-pumps in one or more of the mills are put in operation; if a very large quantity is wanted, the force-pumps in mills in other parts of the city are put in operation. A frequent result in such cases is that the quantity of water in the reservoir is greater after the fire than before; this arises from a greater number of force-pumps being put into operation than necessary, the excess of water pumped passing up to the reservoir. Safety valves, similar to those used on steam boilers, are applied at several points on the 8-inch main pipe, to relieve it from excessive pressure due to the action of the force-pumps.

Sprinklers within a few years have been extensively introduced

* From the Journal of the Franklin Institute.

into the Lowell mills, and, in connection with the system of reservoir and mains, are considered the most effective means known for extinguishing fire. In some of the departments of a cotton mill, fire spreads over a whole room with such rapidity, that hydrants or other ordinary means, seem to be wholly inadequate to extinguish it. In such case, a suitable sprinkler appears to afford the greatest protection practicable.

As constructed at Lowell, a sprinkler consists of a net-work of pipes perforated with small holes, so arranged and directed that when a valve connecting the sprinkler with the main pipes is opened, the water will flow into all parts of the system of pipes, and escape at the perforations, with sufficient force to wet thoroughly, and in a very short time, every part of the room it is designed to protect. The idea is not new or peculiar to Lowell, but perhaps it has been more extensively and systematicallly adopted there than elsewhere. It was first introduced at Lowell, in the year 1845, into the picking-room of the Suffolk Manufacturing Company, by Mr. John Wright, the agent of that company. As is well known, this department of a cotton mill, is peculiarly liable to fire, from the action of the machinery on the cotton, and particularly on the foreign substances which are often found mixed with it.

After the construction of the reservoir, the advantages of the sprinklers, when used in connection with it, were so obvious, that they were soon introduced into the picking departments of all the cotton mills in Lowell. In 1852 and 1853, sprinklers were put into the roofs of the mills. In one of the old mills, which have slated roofs, the plan adopted was to carry a six-inch pipe, from the main in the mill yard, up near the middle of the mill to the level of the perforated pipe, which was placed a few feet below the ridge pole, and extended the whole length of the mill, in a single line, gradually diminishing in size, from 5 inches in diameter, near the middle, to 3 inches at the ends. This pipe was perforated with two holes, $\frac{3}{16}$-inch diameter, in each foot in length. These holes point in different directions, so as to wet, as far as practicable, all parts of the roof. The water after striking the roof, falls, and a large portion of it finds its way into the stories below. The valve connecting the sprinkler with the main pipe is placed in or near the ground, usually in a pit in the ground, near the mill, so as to be always readily accessible, and the water being constantly maintained in the main pipe at a high pressure, the sprinkler can be put in operation with very little delay.

The roof sprinkler is deemed a very great security against heavy losses by fire, as it affords the means of applying a large volume of water at the top of the mill, where from the elevation it would otherwise be difficult to apply it. This apparatus is expected to discharge about 400 gallons of water per minute, and is intended to be used only for a few minutes at a time, unless the fire is confined to the roof. Its efficient action requires that most of the hydrants should be shut off.

Between the years 1853 and 1859, sprinklers had been introduced into many of the carding and spinning rooms of the cotton mils, which rooms are particularly liable to the rapid spread of fire. In the year 1859, sprinklers were required to be put in all such rooms, as well as into all picking rooms, and all other buildings and rooms liable to the rapid spread of fire or difficult of access.

It has been found by experiment that about 450 gallons per minute is the largest quantity of water which can be drawn from the main pipes in some of the mill yards, from the reservoir alone, and maintain an effective working pressure. If a large fire should occur when the canals are drawn off, as they often are during the night and on holidays, to enable repairs to be made, the force-pumps could not be operated, and the supply of water would be limited to that which could be drawn from the reservoir. By operating one section at a time, the sprinklers can be effectively used in such an event; but in a large fire, the supply of water would be much too small for the efficient action of all the apparatus provided. The remedy is a larger main pipe, an improvement we are looking forward to in order to perfect the system.

As an illustration of the arrangement of sprinklers adopted at Lowell, the following description is given of the apparatus in the Tremont Mill, which was erected in the year 1863.

The building is about 440 feet long, and 70 feet wide inside; with five full stories and a roof nearly flat. The floors are of wood, supported by two rows of pillars. The beams are about 16 inches deep, placed about 8 feet apart. The floors are made of three inch planks laid directly on the beams, with a boarding above and another below, between the beams, forming the ceiling. The three upper stories are furnished with sprinklers, arranged in three sections in each story. Each section is supplied by a rising main pipe, of cast-iron, 6 inches in diameter, connected with the 8-inch main pipe in the mill yard, and furnished with a stop-gate, placed in a pit in the ground, deep enough to be completely protected from frost. The handle of the stop-gate is constantly attached to the gate, and extends above the level of the ground, so as to be readily accessible at all times. The rising main is carried up outside of the mill wall, and between the windows, in order to be out of the way of heat, when not filled with water, in case of fire in the mill. Near the level of the perforated pipes in the third and fourth stories, the rising mains are carried through the wall, and connect, on the inside, with the horizontal mains, which lie just below the floor beams, and close to the wall of the mill, and extend each way as far as the section of sprinkler extends, or about 70 feet. The horizontal mains diminish in size as they recede from the rising main. At intervals of about 8 feet, corresponding to the bays of the mill, lines of perforated wrought iron pipes branch off from the horizontal main, first upwards, by short vertical pipes, equal in length to the depth of the beams, in order to reach the level of the ceiling between the beams; thence across the whole width of the mill, in the middle of each bay, the pipe being in contact with the boards forming the ceiling of the room. The diameters of the perforated pipes diminish as they recede from the horizontal main, being $1\frac{1}{2}$ inches in diameter at the origin and $\frac{3}{4}$-inch in diameter at the other extremity. The perforations are $\frac{1}{10}$ of an inch in diameter, 18 inches apart on each side of the pipe, making about 92 perforations in each line. These holes point a little above the horizontal, so that the jet of water will strike the ceiling a few inches from the pipe. The water issuing with considerable force, it will follow along the ceiling, falling in drops at short intervals, a portion of it reaching the beams, which are about $3\frac{1}{2}$ feet distant, on each side of the perforated pipes. In the upper story, the ceiling rises in the middle, corresponding to the pitch of the roof; the horizontal main is placed in the middle of the room, with the small pipes branching out on each side, and perforated the same as in the stories below.

The whole length of perforated pipe in the three stories of the mill is a little more than two miles, each section having about 1260 feet, containing about 1650 orifices. In one section the total area of the orifices for the distribution of the water is about 13 square inches; the sectional area of the rising main is about 28 square inches; the proportion of sectional area in the rising main to the sum of the areas of all the orifices of distribution, being a little greater than two to one. In proportioning the diameters of the pipes throughout the whole system, substantially the same proportion is observed; thus, in the lines of perforated pipes across the mill, the sum of the areas of all the orifices of distribution is about 0·723 square inches; the sectional area of the pipe at its origin is 1·767 square inches, which is rather more than double the sum of the areas of the orifices of distribution. If the pipe at its origin had a diameter of 1·357 inches, its area would have just been double that of the sum of the orifices, but this is a size not usually manufactured. Of course there is no objection to the use of a pipe somewhat larger than the rule requires.

The pipes and perforations in each section of the sprinkler, are designed to discharge about 450 gallons of water per minute, which is about all that can be drawn from the main pipes in the mill yards from the reservoir alone, and maintain a sufficient working pressure; and, of course, only one section at a time can be efficiently operated, unless the force pumps in that mill, or in some of the neighbouring mills, are in operation.

The area of floor covered by one section of the sprinkler is about 10,300 square feet. The water discharged in one minute, would cover this area to a depth of about $\frac{1}{14}$ of an inch, which is at the rate of $4\frac{2}{7}$ inches per hour. The fall of water in a thunder shower is sometimes as great as this, but in this latitude it is very rare. There has been no opportunity as yet, to test the effect of any of the larger sprinklers, like that just described, in extinguishing a fire; many of the smaller sprinklers in the picking-rooms have however been used, and their operation has been in the highest degree satisfactory. There have been several opportunities for testing the larger sprinklers when there has been no fire; in every case, where the proportion between the sectional area of the pipes, and the area of the orifices of distribution which they supply, has been not less than two to one, the operation has been satisfactory, and in cases where sprinklers are in the lower stories, with short and well arranged supply pipes, they have operated satisfactorily, with a proportion between supply pipe and orifices of four to three. The proportion of two to one is, however, preferred. At Lowell the surface of the water in the reservoir is about 100 feet above the top of the highest mill in the city. In order that sprinklers should operate with equal efficiency, with a less elevated reservoir, the proportion between the sectional areas of the supply pipes and the orifices of distribution should be proportionally greater. In cases where the reservoir is but little above the level of the top of the building, a proportion as large as four or six to one may be necessary.

The following table is computed for the proportion between the sectional area of the supply pipe and the sum of the areas of the orifices which it supplies with water, of two to one. For a proportion of four to one, the number of orifices which can be supplied is one-half that given in the table; for a proportion of six to one, the number is one-third that given in the table.

Diameter of supply pipe.	Number of orifices of distribution of different sizes which can be supplied.					
Inches.	3/16 inch	5/32 inch	1/8 inch.	1/10 inch.	3/32 inch.	1/16 inch.
8	908	1312	2048	3204	3644	8195
7	696	1004	1568	2452	2788	6274
6	511	738	1153	1802	2050	4610
5	355	513	800	1251	1424	3201
4½	287	415	648	1013	1152	2592
4	227	328	512	801	911	2049
3½	174	251	392	613	697	1568
3	128	185	288	450	513	1153
2½	80	128	200	313	356	800
2	57	82	128	200	228	512
1¾	43	63	98	153	174	392
1½	32	46	72	113	128	288
1¼	22	32	50	78	89	200
1	14	20	32	50	57	128
¾	8	12	18	28	32	72
½	3	5	8	12	14	32

PECULIARITIES OF INDIAN ENGINEERING.

By Major J. G. Medley, R.E.

In this paper I propose to draw attention to some of those peculiarities in Indian engineering, which will serve to show the conditions under which work has to be executed in this country, (India,) and how far they differ from English methods. The sketch will not, perhaps, be altogether destitute of interest to many who are in India.

First, as to the agency. Except forts, arsenals, dockyards, barracks, and the like, there is scarcely a single public work in England in which the Imperial Government is directly interested; for even such works as jails, roads, &c., belong to the counties, or to recognised local interests, while the great mass of important works, such as railways, harbours, &c., belong to joint-stock companies, and are private property.

In India, the Government is the constructor and maintainer of nearly every public work throughout the country. Not merely works which specially appertain to an immense military establishment, but every road, bridge, church, court-house, jail, &c., has to be built from Imperial funds, and through Government officers. Nor can even the railways be excepted, for though the capital employed is not its own, yet the controlling power possessed by Government is so great,* that not the smallest work can be undertaken, nor the salary of the least official paid, without its written authority.

For the above work, a great department of state, the Department of Public Works, is specially provided, by which a systematic control is maintained over a vast body of officials, European and native, acting as engineers, overseers, &c., from the secretariat down to the meanest employé.

But another distinctive difference between the agencies employed in England and India is, that in the former country work is executed almost invariably by contract, while in the latter daily labour employed and paid by the engineers is as invariably used. It is true that every effort is being made to introduce the contract system, and that it is generally in vogue in the presidency towns, and on most of the great railway works, but over the whole country the vast mass of the Government work is done by daily paid labour, and the extra work thereby thrown upon an engineer may be easily conceived.

In another very important matter do the functions of the Indian engineer differ much from his brother in England. In many parts of the country there is no organisation of labour whatever, and, when works have to be executed, the engineer has to collect and train his workmen, to make arrangements for carriage,* to make his own bricks, burn his own lime, cut his own timber, and in a word superintend a hundred petty details, which in a civilised country are undertaken by a hundred different men, each skilled in his own peculiar business

Of the workmen themselves, much good may be said. That they have the usual prejudices of ignorant men to the introduction of new ideas, and new methods of working, is to be expected, but they are not worse than others in that respect, and if well managed are as a rule both intelligent and teachable. Excellent masons, carpenters, and smiths abound in the country. The machinery in the various railway workshops is managed by natives under European superintendence, and though there are no native engine-drivers as yet, we shall doubtless have some before long.†

The most striking thing to the engineer fresh from England is the total absence of the ordinary mechanical appliances for executing work. Vast earthworks are still made by the help of the phourah, or native spade, and baskets carried on the heads of women and children. Wheelbarrows are scarcely ever seen; horse carts still more rarely. For getting water out of foundations, &c, pumps are coming into use, but in general the primitive native modes of baling, or the churus (leather bag), or Persian wheel worked by bullocks, are still employed. Bricks and tiles are almost invariably hand-made, and the pug-mill unknown; the saw-pit is never used.

Of course, the principal reason for this is the comparative cheapness of labour, but if the rate of labour increases for a few years longer, as it has done for some time past, the introduction of more elaborate appliances will become essential. At present, except the railway workshops and those established at Roorkee, there is no steam machinery in the country, unless at the presidency towns. Machines driven by wind power are also unknown; it is difficult to say why. Of the enormous water-power available on the numerous canals and rivers, very little is utilised. Sawing machines are here and there put up, and the common punchukkee, or native corn-mill, is everywere seen where there is an available fall. Machinery worked by animal power is confined to water-raising for irrigation purposes, and to one or two primitive inventions employed in manufactures.

Having said so much of the agency employed, let us glance at the materials used, and the works turned out. In Central India and the hilly districts all over the continent, many varieties of excellent building stone exist, and are abundantly used. In the great

* This arises from the guarantee system under which the capital has been raised, the Government guaranteeing a minimum rate of interest (5 per cent.) to the shareholders on all sums passed to capital account. The controlling power is exercised through the Government consulting engineers, who have a veto on almost every action of the company's engineers. The system, though perhaps the best that could be devised at the time, has been productive of much delay, and no little dissension. It would be a preferable course for Government to grant a certain subsidy to the railway company for every mile of line, as completed and open for traffic, and some such arrangement will probably be adopted in future.

* This difficulty of carriage alone, in a country where the distances are so vast, and the means of intercommunication so incomplete, is most serious. The greater portion of the permanent way on the East Indian Railway was brought by native boats up the Ganges, and £100,000 worth of rails, &c., now lie at the bottom of that river. On the Punjab Railway, the materials were brought in boats up the Indus, which were often seven months on the voyage (800 miles), the cost of freight between Kurrachee and Moultan being double the freight from England to Kurrachee. The locomotives after getting to Moultan were dragged up an unmetalled road to Lahore on trucks, by elephants and bullocks—six weeks being occupied in accomplishing the 200 miles. On this line too, which runs through a desert, the first steps of the engineers were to dig wells and build huts for the workpeople, and induce grain merchants to live in the desert to supply their wants. When the writer went down to inspect the first trace of the line with the chief engineer, water and provisions had to be carried on camels to supply the whole party.

† In the railway workshops at Lahore, a short time ago, I saw the carpenters working at regular benches instead of in their own squatting position, and turning out some beautiful specimens of work. The whole of the rolling stock (except the iron-work, which is brought from England) has been made at Lahore for this line by native workmen. At Goojranwalla I saw a Colt's revolver, copied so exactly, even to the engraving on the cylinders, that only very close inspection could tell it had been made by a native smith.

plains of Bengal, Hindostan, and the Punjab, however, brick is the only available material. The English sized bricks, or those of a still larger size, are now coming into general use. The native bricks are very small, excellently burnt, laid with little attention to bond, and with a profuse expenditure of mortar. Bricks are burnt with wood fuel,* in kilns of several kinds; or in stacks like English clamps, with dried cow-dung instead of coal.

Excellent lime is everywhere abundant, produced either from limestone *in situ*, or the boulders found in hill torrents, or the kunkur found in the plains. It is mixed with various substances for mortars, of which pit sand and soorkhee (pounded brick) are the chief ingredients. For very strong or fine mortars, coarse sugar and egg shells are sometimes added.

A great variety of fine timber is found in India, generally brought from the forests in the hills—among which may be noticed saul, a dark, heavy, straight and strong wood, and deodar, nearly the same as the cedar of Lebanon; the former used in the North West Provinces, the latter in the Punjab for every kind of building purpose. Both of these are found in the hills alone, at an elevation of from 2000 to 5000 feet; the trees are cut down and thrown into the rivers, and when these rise the logs are floated down to the plains. In West and South India, teak is in general use. It abounds in the forests of Burmah, being one of the most valuable productions of that Province. Toon, an inferior sort of mahogany, is extensively used for furniture; sissoo or sheeshum, and some of the varieties of acacia, are hard, heavy, crooked woods, used for strength and toughness.

Iron ores of fine quality are abundant in many parts of India, but from the want of fuel and carriage are little worked, and English iron is generally used. Government have made, and are now making, several praiseworthy attempts to develop the manufacture of iron.

Here it may be as well to note one or two specialities of construction employed in India.

In Roads, stone metalling, laid as in macadamised roads, is common enough, but in the great plains of Upper India the peculiar material kunkur is used, and laid in a peculiar manner. It is a species of concretionary oolitic limestone, found in beds close to the surface, and has to be drenched with water, rammed quite smooth, and then suffered to dry before any traffic is admitted. It then makes a white, smooth, and very excellent road covering. In Southern India, laterite and moorum, a sort of red gravel, are commonly employed.

In Foundations, piles are rarely employed, for so many destructive agencies are at work that they would not be lasting. The majority of the water-courses are nearly dry at one time of the year, and this affords great facilities for getting in the foundations of bridges or other works in water. For these the general substitutes for piles are masonry wells or blocks, which are sunk close together, arched over, and on them the piers and abutments are raised; they are also used as foundations for houses in places where the soil is very treacherous. The beds of most rivers in Northern India when bored, show sand to an immense depth. In Bengal alluvial mud is found to as great a depth, and necessitates as much precaution as sand. The dry state of the river beds also gives great facilities for turning arches without the use of expensive centerings. A simple arrangement of dry bricks and timbers are constantly used, built up in the bed of the stream; of course the work is subject to accidents from sudden floods, but these are very rare.

The greatest works as yet executed in India belong, as in England, to the railways. Indeed there are none in the world more interesting or important than the Bhore Ghaut Incline, the Soane and the Jumna Bridges, and other works little inferior to them which might be enumerated. The East Indian Railway, 1000 miles long from Calcutta to Delhi, with the branch to Jubbulpore now under construction, is probably the longest line in the world owned by a single company, as it is certainly one of the greatest triumphs of engineering. The Great Indian Peninsular, and other lines, though inferior in length, are some of them, at least, of equal engineering interest.

With them may be classed the great roads, though the system like that of the railways is still far from complete. The Grand Trunk Road from Calcutta to Lahore, 1300 miles in length, comprises every variety of construction, from the heavy gradients through the Rajmahal hills, to the massive and level embankments between the Jumna and the Sutlej. The Lahore and Peshawur road, a continuation of the Trunk line, 270 miles long, and now rapidly approaching completion, may challenge comparison with any in the world; while in the formidable extent of drainage crossed by it, it probably stands alone. Of others, the Hindostan and Thibet road when finished may take its place by the side of any of the famous Alpine roads; while the great Deccan road, the Assam road, and many others still in hand, are works of considerable magnitude.

Besides the length of the distances to be traversed, it is in the formidable character of the flood waters that have to be crossed that the specialities of their construction are to be sought. Nothing but actual experience will convince the English engineer of the enormous water-way required to pass drainage lines which, seen only in the dry season, are so shallow and often perfectly dry; and scarcely a season passes without the most ample experience being set at naught by the results of some extraordinary flood. The Indus has been known to rise 50 feet in a single night, where confined between its rocky banks at Attock. At a distance of 800 miles from its mouth, I have been in a boat in the middle, and was unable to descry either shore, while the deep channel in one single season has shifted its place laterally as much as 3 miles. Cross this river in the dry season, and the track lies over 10 miles of quicksand and mud, while a channel of 1000 feet in width passes the whole body of water. To carry a road across the valley of such a river, and to bridge such a stream, may well daunt the boldest engineer.

This describes the rivers of Northern India only; those of Southern and Central India have also their peculiarities, which it would be tedious to detail here.

It is, however, in the great irrigation works that have been or are being constructed in India, that the peculiarities of Indian engineering are more especially to be sought; for, except in Italy, those works have no counterpart in Europe. The Ganges canal, 900 miles long with its branches, and pouring its waters over a million of acres through 3000 miles of distributing channels; the East and West Jumna canals, 200 and 500 miles long respectively; the Baree Doab canal, also 200 miles in length, are works of which any country may be proud, and in the principles and construction of which engineers have to learn much which they cannot be taught in England. An entirely separate class of works are the great weirs and tanks of Madras, wherof the works on the Godavery are the finest examples, and which are also purely Indian specialities.

Next, a word may be said as to Indian architecture. The architect and engineer are generally one, and he also is the constructor as well as designer. The requirements of the climate necessitate modes of construction differing from those in England, but until lately we have not managed to combine coolness and ventilation with much architectural beauty. A reform in this respect is however in progress. We are at least erecting handsomer buildings, and attention is being directed towards cooling them effectually. The difficulties are great, for what does for the moist heat of the Lower Provinces, will not answer for the fierce dry heat of Upper India, which it is necessary to exclude for many months all day long, unless the air is artificially cooled before being admitted.* Moreover, the cold in the winter is often excessive, the average extreme range of the thermometer between summer and winter being fully 100° in the Punjab, while in Bengal the temperature is much more equable, the range not exceeding 70°. With all these drawbacks, however, many fine public buildings have been completed, many more are being constructed and projected, and churches, railway stations, and government offices are rising fast, which would do no discredit to any capital.

Some specialities of construction which are common to most Indian buildings attract the attention of the new comer. Except in the presidency towns, they have no upper story, partly from considerations of expense and partly because the upper rooms get very hot during the dry months. The roofs are either thatched or tiled, or else are flat and covered with brick and lime plaster. The thick beams supporting the roof are as a rule left exposed below, as ceiling cloths are apt to harbour vermin and conceal the depredations of white ants. The room walls are very rarely papered, being usually plastered and white-washed. Wooden floors would be too perishable and dear, so floors of flat tiles or of lime plaster are substituted. Doors are numerous, and invariably

* Except in a few places where coal is found. No coal worth working has yet been discovered in Northern India. The locomotives burn wood, and fuel is scarce and dear.

* The temperature of the air at midnight in Upper India during the months of May and June is often over 100°.

double, opening in the middle. Verandahs all round a house are considered indispensable.

In many of the most important and interesting branches of engineering little has been done as yet in India; in drainage, water supply, and gas lighting, we are now only making a commencement even in the presidency towns. A fine scheme however is in progress for the drainage of Calcutta, and a similar project will shortly be submitted for Madras, while the drainage and conservancy of native towns and European cantonments are engaging much attention.

In the improvement of our great rivers for inland navigation, little or nothing has been done, but many navigable canals are at work in Madras and Bengal, and others are in progress. In Bengal, inundations from the sea and rivers have also given us practice in the important subject of embankments; and the Hidgelee sea dyke, when completed, will it is said be a noble work.

Of military engineering not much has to be said. Like the Romans of old we encamp our troops in the open, instead of shutting them up in forts. Our arsenals are for the most part inside old native forts slightly improved, and except Fort William and the outposts on our N. W. frontier, there is scarcely a single fort of modern construction in the country.

Closely allied as it is to engineering, a word must be said in praise of that noble work, the Indian Survey, of which too little is known to the scientific world. While the trigonometrical department is covering the country with a net-work of triangles, fixing the position of the principal stations with an accuracy that has not been surpassed (if it has been equalled) in any European country,* the topographical department is busy in delineating the features of the mountain districts in a series of maps,† whose fidelity is only equalled by the difficulties which have attended their completion, and the revenue department is mapping the plains to a degree of detail which shows not only every village but every field in each village.

Incomplete as this summary has been, I will hope that it may be useful in arousing some interest in England in the peculiarities of Indian engineering.

WORKS AT LAMBTON CASTLE, DURHAM.

The following particulars of the works, for some time and still in progress at Lambton Castle, were communicated by Professor Sydney Smirke, at the June Meeting of the Northern Union of Mechanics' Institutions, at Chester-le-Street.

After some preliminary remarks, the Professor said, as a work of venerable age Lambton Castle has, and can have indeed, no attractions. It is graced by none of the charms of genuine antiquity, though it may well lay claim to that regard and that careful survey which your respect for its noble possessor, rather than any architectural merits, will secure for it. I am induced to say this, not from any affectation of modesty, but for fear you should suppose that, in entering into what may be a tedious description of the works at Lambton Castle, I am inviting, or awaiting, your approval of them. I think that a plain account of a large and important work of this nature, and of the particular views that have influenced the designers of it, may be of some service to those who are engaged in the same pursuits as myself.

Harraton Hall, now Lambton Castle, is situated about a mile below Chester-le-Street, upon the banks of the Wear, a river abounding in romantic scenery. It was anciently the seat of the D'Arcys, who conveyed it to the Hedworths, or Headworths; and after the decease (in 1688) of the last male heir of that family it became the property and seat of Mr. Ralph Lambton, through his wife, who inherited it on the death of Mr. John Hedworth. Some fifty or sixty years ago the grandfather of the present Earl caused to be built a residence on, or nearly on, this spot, and he could hardly have selected a more agreeable site; but, unfortunately, the architect was not aware of the singular nature of the spot so selected. Highly picturesque as it is, rising magnificently above the valley of the river on whose steep and richly-wooded banks the castle stands, it happened that the whole neighbourhood had at a remote time been undermined in search of coal. At the depth of about 69 fathoms below the surface of the hill, there were a series of beds of coal, reaching downwards to I know not what depth. These beds had been worked out, and had then been deserted and forgotten, so that the beautiful knowle, whilst it appeared to be as solid as any other portion of the great mountain range of coal measures, was in truth a most unsubstantial tract of perforated ground, unable to bear the weight artificially imposed upon it. The castle showed early symptoms of the gradual subsidence of the earth on which it stood, and, by the time the present earl came into possession of the estate, the building had become in some parts insecure. His lordship had, in fact, to chose one of two courses; either to take down the structure, and abandon the site as a place of residence; or to restore to the hill that stability of which the miners had deprived it, and, when thus rendered solid and trustworthy, to re-erect thereon the castle.

The beauty of the surrounding scenery, as well as, perhaps, a not unnatural partiality for a site already selected by his predecessors as their residence, ultimately induced his lordship to adopt the latter course, nothwithstanding the large expense that was inevitably occasioned by the adoption of it.

Accordingly, over the whole area occupied by the castle, the succession of empty coal seams were all diligently and substantially built up or "stowed" with solid masonry. The very core of the hill was restored, not by occasional props or piers, but by a series of solid, continuous, beds of masonry.

I need not tell you how difficult, tedious, and expensive this work necessarily was; nor need I dwell on the serious responsibility that must have been felt by all who in recommending this course had, as it were, guaranteed its success. The process occupied upwards of six years, and till this was completed little advance could be made on the superstructure. This remarkable work, however, was undoubtedly successful, and is a great triumph of practical skill.

The offices and private suite of apartments were, for the most part, rebuilt at the beginning of the year 1862, when Mr. Dobson fell ill. Under these circumstances his lordship thought proper to place in my hands the further conduct of the work. The completion, therefore, of the private suite of apartments and the whole of the reception-rooms has been so carried on.

I will now call attention to such portions of the building as seem to me most likely to interest practical men.

With regard to the foundations, it will be readily understood that the very unfavourable nature of the subsoil rendered them a work of primary importance. The principal walls have had to be taken down, in most cases, to the depth of 15 feet below the cellar floor, and under them has been placed a bed of concrete 10 feet wide and 8 feet deep.

There is no sham more discreditable than the mode of construction by which we have walls of formidable apparent thickness, but consisting in truth of two thin faces of worked stone, filled in between with loose rubble. Nor is this a dishonesty chargeable on modern contract work alone. It is a sham of ancient standing, met with, not unfrequently, in buildings of various mediæval dates. A long list might be drawn up of the towers and spires that have prematurely perished or become rent in twain from this cause.

We are apt to look back upon our ancient worthies with awe and reverence, as to men of a golden age; but, "'Tis distance lends enchantment to the view," and could we go back again to the time of the cowl and hauberk, we should probably find that human nature is not so much worse than it was of yore, and that amidst those freemasons of pious simplicity not a few rogues might have been found.

After entering the outer hall (which is so placed as to prevent the cold winds, which are here often very violent, from rushing into the interior and so chilling all the adjacent apartments) we are introduced into the great hall, which was always an essential part of the baron's residence in feudal times, and which I expect in the present case will be found of great and various utility. Besides forming a handsome means of communication between all the principal parts of the house, it will afford room for recreation and exercise to both young and old in bad weather, and on state occasions will become a brilliant hall for receptions, banquets, or balls.

The floor will be laid with parqué panels of wainscot, and the walls will be similarly panelled, the upper part of them clothed with pictures, and perhaps armour and banners. The

* The Supdt. G. T. Survey, Major Walker, has lately proceeded to Europe to confer with the Russian Government on the means of connecting the great series of Indian triangles with that of the Russian survey.

† The map of Cashmere lately completed by Capt. Montgemerie, R.E., has elicited the warm approval of the distinguished president of the Royal Geographical Society. Many of the trigonometrical stations were above the line of perpetual snow, where the surveyors had to stay for days together waiting for favourable weather for their observations.

great end window will be glazed with richly stained glass, which, together with the side windows, is now busily engaging the attention of Mr. Wailes. The carved oak roof of the hall is a specimen of sound workmanship by the Burnups, of Newcastle, worthy to be compared in execution with any similar work of the fifteenth century.

These framed timber roofs are one of the special glories of Gothic architecture, contrasting favourably with the cobweb-like structures to which engineers are so prone, and of which it may be truly said that they are "a work to wonder at;" the wonder, however, being that they do not more frequently collapse, and resolve themselves into their simple elements, a heap of rods, bolts, and bars.

It may be of some interest to compare the dimensions of this hall with those of some similar halls of various dates. The following are a few examples:

	Ft.		Ft.	Height to Ridge.
Westminster Hall, London	238	by	67½	90 ft.
Guildhall, London	153	by	50	82
Lincoln's Inn, London	120	by	45	60
Raby Castle, Durham	120	by	35	—
Christchurch, Oxford	115	by	40	50
Whitehall, London	110	by	55	55
Hampton Court Palace	106	by	40	60
Eltham Palace	101	by	36	54
Middle Temple, London	100	by	40	50
Mansion House, London	90	by	50	60
St. Stephen's Hall, Westminster	90	by	30	60
Lambton Castle, Durham	94	by	36	64

Proceeding onwards we enter the principal staircase, which is 50 feet by 24 feet, and 36 feet high. Its walls will afford ample space for the exhibition of pictures and other objects of interest. From the deeply embowed window at the first landing there is a charming view of the wooded hills which surround the mansion and of the valley of the Wear, whose stream runs 120 feet below.

Returning now to the hall, a central door towards the east leads into the dining-room, 59 feet by 25 feet, and 22 feet high. Although this room is in temporary use, its final decorations are postponed until a more convenient time; the ceiling will demand gilding and coloured treatment.

A door on the west side of the hall leads into the drawing-room, overlooking the terraces and garden. It is 66 feet by 26 feet, exclusive of the bow, and 22½ feet high. The walls will be richly clothed by the ample stores of works of art in his lordship's possession. The floor will be parquetted in various woods. The carved chimney-pieces, rising to a height of 18 feet, have been executed by Messrs. Mazaroz & Co., a firm in Paris, eminent for artistic workmanship of this nature. It is a fact well worthy of notice and emulation, that, such is the energy of our French neighbours, these elaborate chimneypieces, together with those equally enriched in the hall, and that in the state bedroom, comprising together a prodigious amount of carving, were modelled, carved out of the solid oak, framed and fitted together, packed up, and delivered from Paris at the castle, within three months.

RAILWAY OVER THE MONT CENIS.

A series of official trials on the proposed railway over Mont Cenis, to be used during the construction of the celebrated tunnel through the mountain, has just been concluded. Captain Tyler, R.E., was commissioned by the English Government to be present at these trials, and to report thereon, which he has recently done. The experiments were to be made with the loads and at the rate of speed required to carry out the programme of the projectors for trains crossing the mountain between Susa and St. Michel, carrying fifty passengers, their baggage, and the mail, and performing the distance in 4½ hours. But throughout the trials the stipulated speed was exceeded. The portion of the high-road over the Cenis that has been granted for the railway line is the outside-skirting, that is to say, the edge of the precipice. Measures had to be taken to obviate risk, and persons who have well examined and repeatedly travelled over the portion of the line already constructed, have expressed a most decided opinion in favour of its safety. Until the contractors had thoroughly satisfied themselves of the possibility of securing complete safety, it would have been folly for them to embark at all in the undertaking.

There is a break of 47·6 English miles, from St. Michel to Susa, in the railway communication between France and Italy by the Mont Cenis route, and the contract time allowed for travelling by diligence between those two places is 9 hours in summer, and 10½ in winter. The passage of the mountain, which may be said to commence on the French side at Lanslebourg, is by an excellent road, 9 to 10 metres (say 30 to 32 feet) in width, and on an average gradient of 1 in 13; but the traffic is much impeded during the winter season by snow; and considerable risk is incurred in some states of the weather from the fall of avalanches, and from the difficulty of guiding the heavy diligences over ice and snow in the descent. During portions of the winter, indeed, the service is performed by sledges, and the time occupied by the journey is uncertain, depending on the state of the weather.

To save time, and to obviate the inconveniences of this passage, the Grand Tunnel of the Alps is in course of construction between Modane and Bardonèche for a length of 12,220 metres (7·593 miles). In this tunnel headings have been driven for 2011 metres from Modane, and 2700 metres from Bardoneche, leaving 7509 metres (about 4⅔ English miles) to be pierced. The boring machines in this tunnel, ingeniously contrived by Messrs. Sommeiller, Grandis, and Grattoni, are worked by air, which is compressed to five atmospheres by water-wheels in the valley below, and about a mile and a half distant from them; and the headings are formed by successive explosions of gunpowder, in the usual way, as soon as the holes, about 3 feet deep, have been formed (and tamped) in the rock.

It is stated that 400-horsepower has been exerted by five of these water-wheels at Modane, to provide 27-horsepower working nine jumpers at the face of the excavation, and to afford indifferent ventilation (except at the spot where the boring machine is at work) to the interior, while £8000 or more has been recently expended in constructing cylindrical boiler-shaped reservoirs for compressed air, to contain a supply sufficient for about half-a-day's working in the tunnel. These reservoirs are filled during the intervals when the boring machines are not at work.

Captain Tyler states that, "looking to the rate of progress which has hitherto been effected, and the probable nature of the rocks, it cannot be expected, without taking into account any extra difficulties of ventilation, or from water, which may be encountered, that this tunnel can be completed in less than from seven to eight years. There are other works also on the permanent railway, as at present projected, including other tunnels, which will occupy many years in construction."

Under these circumstances, Mr. J. B. Fell has proposed to the French and Italian Governments, on behalf of Messrs Brassey and Co., to construct a railway from St. Michel, over the Mont Cenis to Susa, to be used pending the completion of the grand tunnel and the permanent railway to be connected with it. Mr. Fell has asked for no pecuniary aid from either of those Governments, as the association with which he is connected are confident of making a profit out of the work, besides reimbursing themselves for their outlay of capital and interest, by the time that the tunnel is completed.

But the gradients contemplated were such as could not be surmounted by any locomotive engine working with a load, on the ordinary system of trusting to its weight for adhesion between its wheels and the rails; and it was considered that the best method of obtaining extra adhesion would be by the revival of a system, long since patented, but never carried out, of adding a third rail between the ordinary bearing rails, to be acted upon by horizontal driving wheels on the engine. A locomotive engine was accordingly constructed, from one of a number of designs which have been patented and described by Mr. Fell, with two pairs of horizontal, as well as two pairs of vertical driving wheels; and an experimental line 800 yards long was laid down in Derbyshire, on the Cromford and High Peak Railway, with the permission and assistance of the London and North Western Railway Company. The gauge was 3′ 7 ⅜″, and there were 180 yards of straight line on a gradient of 1 in 13·5, and 150 yards of curves, with radii of 2½ and 3½ chains, on a gradient of 1 in 12. The third rail upon this line, to be clipped between the horizontal driving wheels of the engine, was laid on its side 7½ inches above the other rails. In the course of a series of experiments, carried on from September 1863 to February 1864, the first engine that was constructed, working up to a pressure of

120 lb. to the square inch, never failed, as I am informed, to take a load of 24 tons up the above inclines and round the above curves; and its maximum load was 30 tons. The outer cylinders, working on the four vertical wheels, which carried 16 tons when the engine was fully loaded, could only draw up, besides the weight of the engine, a loaded waggon weighing 7 tons; while the inside cylinders, acting upon the horizontal wheels, which pressed with 12 tons against the middle rail, enabled the engine to take up 24 tons on the same day, and under the same conditions. The inside cylinders alone were able to carry up the engine itself round the curves, and they exhibited the power of taking up altogether 17 tons, as against 23 tons for the outside cylinders, which were nearly in proportion to the pressure and weight upon the horizontal and vertical wheels respectively. The experiments on the High Peak Railway were so successful that it was determined, with the permission of, and for the satisfaction of, the French Government, to repeat them on a larger scale on the slopes of the Mont Cenis; the Italian Government having undertaken to grant a concession to the promoters for the south side of the mountain, conditionally on a concession being obtained from the French Government for the other side; and the French Government having promised their concession, after some correspondence and delay, on the condition of the practicability of the scheme being demonstrated.

The experimental line which has now been constructed on the Mont Cenis, is situated between Lanslebourg and the summit, commencing at an elevation of 1622 metres, and terminating at an elevation of 1773 metres (or 5815 English feet) above the sea. It is nearly 2 kilometres, or a mile and a quarter in length, and rises for the whole of that distance with a mean gradient of 1 in 13, the maximum gradient being 1 in 12. It passes round a sharp corner, joining two of the zigzags of ascent, on a curve of 40 metres, or about 2 chains' radius, and except at this point it is laid on the outside of the road, occupying a width of 3½ to 4 metres, and leaving 5 metres and upwards clear for the road traffic.

The portion of the road which remains appears to be quite sufficient for the circulation of the existing traffic. The diligences and other conveyances traverse the mountain with no more difficulty than before, and with the additional protection of the railway fence between the road and the precipice. Less inconvenience has been experienced than was anticipated from working the locomotive engines so near to the public road; and as the same horses and mules are, for the most part, employed upon the mountain, they will become more and more accustomed to the noise of the engines and trains. During three months of working no accident appears to have occurred. The traffic on the road, will of course, be comparatively inconsiderable after the opening of the railway, and there can be no doubt that the portion of road remaining for it will then be amply sufficient for all purposes.

This experimental line has been purposely constructed on the most difficult portion of the road on which it is proposed to leave the railway without covering; and it was well tested as to the difficulties arising from snow during very severe weather, in the early part of the present year. The result could hardly have been expected. Better adhesion was obtained on the rails in the winter than can be looked for in the summer season. The snow, when removed from the rails in hard weather, left them dry and in good condition, while the peculiar dust of the roads, especially when mixed with water, renders them comparatively greasy or slippery.

This line is laid on a gauge of 1·10 metre or (3′ 7⅜″), with rails borrowed from the Victor Emanuel Railway Company, of the I section, weighing about 75 lb. to the lineal yard. The bearing rails are fished at the joints, and are supported in cast-iron chairs, which are spiked in the ordinary way to transverse wooden sleepers, 3 feet apart. The only peculiarity (beside the steep gradients and sharp curves) consists in the addition of a middle rail of the same section, which is laid on its side between the other two, and at an elevation (to its centre) of 7½ inches above them. This rail is supported partly on cast and partly on wrought iron chairs, weighing 20 lb. each at the joints, and 16 lb. each in the intermediate spaces.

These chairs are now 6 feet apart on the straight line, and from 2 to 3 feet apart on the curves, and the joints of the middle rails are not yet fished. But it is intended to add fish-plates immediately to the joints of these rails, and when the line is laid permanently to place the chairs 3 feet apart on the straight line, and 1 ft. 6 in. apart on the curves, besides securing them to the longitudinal timbers on which they rest by means of through bolts. The longitudinal timbers are 8 inches deep by 12 inches wide, and they are spiked to the transverse sleepers. They will be more securely affixed to them in the permanent road.

The above rails are unfavourable for use as intermediate rails, because the horizontal driving wheels of the engines only bite upon projecting parts of the squared edges of their section; and they are not of the best quality for affording adhesion; but it was an advantage to be able to procure them in the country, and it may be considered that the rails which will be specially supplied for the permanent line will, at all events, not be less efficacious.

The whole line from St. Michel to Susa will be on average gradients (supposing the culminating point in the middle) of 1 in 25·6. The steepest gradient will be 1 in 12, and a middle rail will be added to the permanent way for all gradients steeper than 1 in 25.

Out of 1960 metres on the experimental line, there are 850 metres of curves, in 450 of which the radius of curvature varies from 84 to 40 metres, while in the remaining 400, the radius measures 100 or more metres. The proportion of curves on the whole line between St. Michel and Susa will be much less; and Mr. [illegible] proposes, by a happy idea, to modify the gradients on the sharper curves, and to make the gradients on the straight portions of the line contiguous to them more abrupt, though not steeper than 1 in 12. The extra resistance that would otherwise be afforded, in consequence of the friction of the engine and vehicles in passing round the worst curves, will thus be partly avoided, and the tractional resistances over the different parts of the line will be more nearly balanced, because the sharpest curves and the steepest gradients will not occur anywhere at the same point.

There will be ten level crossings of the road, and six of them on gradients steeper than 1 in 25. The middle rail will be left out at the point of crossing in some of these cases, and will probably be passed by ramps (for animals and vehicles using the road) in others.

The covered ways on different parts of the mountain will extend, altogether, over from 12 to 15 kilometres (7½ to 9½ English miles), but the latter amount has been provided for. They will be of three descriptions, comprising a wooden roof and sides for, say 5 kilometres, to keep off light falling snow; a structure of wood, strengthened by iron, for 7 kilometres, as a protection where the snow drifts in deep masses; and a strong masonry arch, for 3 kilometres, in passing the various runs of the avalanches.

There are no exact records of the amount of snow that falls upon the Mont Cenis; but it appears that the cost of clearing it sufficiently to keep the road open for traffic is at present about 12,000 francs annually, as against 31,900 francs on the average for the St. Gothard. The cost of clearing it for the use of the railway, and the difficulties which it would occasion to railway traffic, would be small, compared with its present cost and the difficulties of the road traffic, for several reasons. In the first place, the railway would be under cover in those parts of the mountain where the snow would occasion the greatest risk and inconvenience. (2) The railway would generally, when not under cover, be on the outer side of the road. (3.) The locomotive engines would be available for working the snow ploughs, when fresh falls of snow necessitated their use. The cost of clearing snow from the railway on the Semmering incline is given at 200 francs per kilometre per annum.

The two locomotive engines now on the Mont Cenis, have been designed with a special regard to three objects. 1. To develope a maximum of power with a minimum of weight, so as to leave as great a surplus as possible for conveying traffic on steep gradients. 2. To afford extra adhesion, independently of their weight, by means of horizontal wheels pressed by springs behind the axle boxes against an intermediate rail. 3. To work at moderate speeds and round very sharp curves.

No. 1 engine weighs 14 tons 10 cwt. when loaded with coke and water. Its boiler is 7′ 9½″ long, and 2′ 9″ in diameter, and it contains 100 tubes of 1½″ external diameter. It has a heating surface of 420 square feet, and a grate area of 6′ 6″. It is provided with four cylinders, two outside cylinders 11¼″ in diameter, with a stroke of 18″, for working four coupled vertical wheels 2′ 3″ in diameter, with a wheel-base of 5′ 3″; and two inside cylinders 11″ in diameter, with a stroke of 10 inches, for working four horizontal coupled wheels 1′ 4″ in diameter with a wheel-base of 1′ 7″. It has now a pressure of 16 tons on the horizontal wheels, 4 tons more than was at first applied to them; and about the same weight as is carried from the weight of the engine by the vertical wheels. Guide wheels have also been added to the trailing end of the engine to act upon the middle rail.

This engine labours under serious disadvantages, inasmuch as its machinery is too much crowded together for convenience in re-adjustment or repair; its boiler power is not sufficient for working the fast traffic of the Mont Cenis; and the oil from its machinery falls upon the horizontal wheels, and deprives them, to some extent, of their power of adhesion. But it has, nevertheless, gone far to prove the principle which it was to test or establish; and it is, considering the novelty of the undertaking, a surprising success.

In the course of two days, I took six trips with this engine up and down the experimental line, carrying each time a load of 16 tons, in three waggons, including the weight of the waggons, and it performed in the ascent 1800 metres in 8⅛ minutes, with a loss of 14 lb. of steam, and of 5¼ inches of water in the gauge glass, at steam pressures varying between 92 and 125 lb. to the square inch in the boiler, as the average of all those experiments.

The speed attained was in every case greater than that which it is proposed to run with the same load with the express trains; and the average speed as above given was at the rate of 13¼ kilometres (or 8¼ English miles) per hour, instead of 12 kilometres (or 7½ English miles) per hour, which is the highest running speed allowed in the programme given to the French government for this part of the line. The weather was fine and calm, and the bearing rails were in first-rate order; but the middle rail, as well as the horizontal wheels, were oily, and therefore in a condition very unfavourable for good adhesion.

The following calculation shows the average work which was performed by No. 1 engine in the course of these experiments. Omitting, in the first instance, the extra resistance from sharp curves and neglecting that from the atmosphere, we have the

Resistance from gravity ...	$=\frac{32\times 2240}{13}$	=	5,514
Friction of Bearing Engine (outside cylinders)	= 16×20	=	320
Friction of Pressure Engine (inside cylinders)	= 16×20	=	320
Friction of Train	= 16×10	=	160
And the tractive force exerted		=	6,314 lb.

1,800 metres ÷ 8⅛ minutes = 5,906 feet ÷ 8⅛ minute = 727 ft. per minute.

And $\frac{6{,}314 \text{ lb.} \times 727 \text{ feet per minute}}{33{,}000 \text{ foot-pounds per minute}}$ ... = 139 H.P.

as against the same load at 12 kilometres per hour ... ... = 125 H.P.

Adding 10 per cent for extra resistance on sharp curves in each case,

139 + 10 per cent. = 153 horse power at 1,800 metres in 8⅛ min.

125 + 10 per cent. = 137·5 horse power at 1,800 metres in 9 ,,

15·5 Excess of horse power above what was required.

The consumption of fuel during these experiments is hardly worth recording, because it was impossible to distinguish between what was burnt while the engine was standing and that which directly contributed to the power exerted. But the engine having been under steam about 3 hours the first day, and 3½ hours on the second day, there was consumed altogether, as nearly as I could ascertain, 583 lb. and 653 lb. of mixed fuel on those days respectively. Of the above time, about 97 or 98 minutes were occupied in running 15 miles during the experiments up and down the line on both days.

This engine has run upwards of 100 miles altogether in ballasting and conveying materials upon the experimental line, carrying loads of from 16 to 20 tons, without accident or difficulty.

No. 2 engine, intended specially for working the traffic of the Mont Cenis, is partly of steel. Its net weight is 13 tons, and its greatest weight, when fully loaded with fuel and water, 16 tons 17 cwt., giving a mean weight of 16 tons, which will be brought up, when certain parts have been strengthened as contemplated, to a maximum weight of 17 tons 2 cwt., and a mean weight of 16 tons 4 cwt. The extra machinery for the horizontal wheels weighs however only 2 tons 13 cwt.

The boiler is 8′ 4½″ long, and 3′ 2″ in diameter, and contains 158 tubes of 1½″ external diameter. The fire-box and tubes contain altogether 600 superficial feet of heating surface, and there are 10 feet of fire-grate area. There are only two cylinders, with a diameter of 15″ and a stroke of 16″, which work both the four coupled horizontal, and the four coupled vertical wheels, which are all 27″ in diameter. The wheel base of the vertical wheels is 6′ 10″, and that of the horizontal wheels 2′ 4″. The maximum pressure in the boiler is 120 lb., and the effective pressure on the piston is 75 lb. to the square inch.

Besides possessing a greater amount of boiler power, this engine travels more steadily than No. 1; its machinery is more easily attended to, and the pressure upon its horizontal wheels can be regulated by the engine-driver at pleasure from the foot-plate. This pressure is applied through an iron rod connected by means of right and left handed screws, with a beam on each side of the middle rail, and these beams act upon volute springs which press the horizontal wheels against that rail. The pressure employed during the experiments was 2½ tons on each horizontal wheel, or 10 tons altogether; but the pressure actually provided for, and which may when necessary be employed, is 6 tons upon each, or 24 tons upon the four horizontal wheels.

The vertical wheels are worked indirectly by piston rods from the front, and the horizontal wheels directly by piston rods from the back of the cylinders. The motions connected with the horizontal wheels appeared to be working perfectly well; but unfortunately some of the parts in front of the cylinder connected with the vertical wheels required strengthening, and it was not desirable, for fear of injury that would cause further delay, to test the engine much or heavily while I was upon the mountain, or until the new parts, which are under construction, had been received from England. I was able, however, to take it up 1800 metres on the experimental line with the same load as before, of 16 tons in three waggons in 6½ minutes, or at a speed of 17½ kilometres per hour, as against 12 kilometres per hour which it is proposed to run with the express trains. The steam pressure in the boiler fell from 112 to 102½, and 3 inches of water were lost in the gauge glass, the feed having been turned on during the latter period only of this experiment. No. 2 engine (whose frictional resistance is 120 lb. less than No. 1 engine, when only 10 tons of pressure are employed on the horizontal wheels) exerted in this instance, omitting the extra resistance from curves, 177 horse power, or adding 10 per cent. for the resistance from curves, 195 horse power, or more than 12 horse power to each ton of its own weight, and nearly 60 horse power in excess of what was required to take the same load up the same gradients and curves at 12 kilometres per hour, as proposed in the programme.

Allowing 4 feet of heating surface to each horse power, this engine ought to be capable of maintaining 150 horse power, or 45 horse power less than it exerted for a comparatively short distance in the above experiments; but considerably more than it will be necessary to exert to carry out the programme. And indeed, a light train, carrying despatches and 50 passengers, and drawn by one engine, would perform the journey without difficulty in four hours, instead of four hours and a half, from St. Michel to Susa.

I observed on the following day, that 40 lb. of steam pressure in the boiler, or one-third of the maximum pressure employed, was sufficient to move the engine alone up a gradient of 1 in 12½; and the friction of carriages or waggons being proportionately much less than that of an engine, the same engine ought, *a fortiori*, to be able to move a gross load of three times its own weight, or 48 tons, at its greatest working pressure, up the same gradient.

The only passenger carriage that has yet been constructed is 6′ 4″ wide, by 12 feet long, by 6 feet high inside. It has a passage down the middle, and six seats on each side, on which passengers sit facing one another. The wheels are 2′ 3″ in diameter, and it is intended that all carriage and waggon wheels shall run loose on one side of the axle. Every vehicle will be provided with a break of the ordinary description, and a large proportion also with breaks acting on the middle rail.

The road traffic between St. Michel and Susa appears from the returns of the Victor Emanuel Railway to show an average increase of rather more than 10 per cent. per annum during the last four years. Estimating the traffic to increase in the same ratio only after the opening of the railway, the total revenue in seven years from 1867 to 1873 inclusive, would be upwards of 27,000,000 francs; and it is considered that such a revenue would leave at the end of that time a clear profit of several millions of francs, after deducting all charges, and after paying interest upon, and paying off, the total bond and share capital of 8,000,000 francs. The value of the railway and rolling stock would also be at the end of that time to the credit of the company. But it cannot be doubted that the passenger traffic would increase in a much greater ratio after the opening of the railway, in consequence of the great saving of time, and the greater comfort and convenience in the passage of the mountain; or that there would be, not only an increase in the goods traffic, but also a prospect of developing a traffic of cheaper goods and minerals which do not as yet pass over the mountain. And the projectors have, further, a reasonable hope of carrying the Indian mail, on the ground that they will be able to save 38 hours of time in its transmission between England and Egypt.

To provide for the carriage of 132 passengers and 88 tons of goods daily, they propose to run three trains each way, namely, one train carrying 40 passengers and their luggage, weighing, exclusive of the engine, 16 tons, and travelling at a mean speed of 18 kilometres per hour for the 77 kilometres between St. Michel and Susa; a second train carrying 26 passengers and 20 tons of goods, and weighing 40 tons, at an average speed of 12 to 14 kilometres per hour; and a third train, carrying 24 tons of goods, and weighing 48 tons, at an average speed of 10 kilometres per hour. The first of these trains they propose to take up the mountain by one engine, and the second and third by two engines each.

The relative distances by the Mont Cenis route from Paris to Turin and Genoa, and the route by Marseilles to those places, may be thus stated:—In proceeding from Paris the two routes diverge from the common point of Macon, and the distances are—

	By Marseilles, English Miles.	By Mont Cenis, English Miles.
Macon to Genoa	559	326
Macon to Turin	659	226

showing a saving in favour of the Mont Cenis route of 233 miles to Genoa and 433 to Turin.

The time that would be occupied in the journey between this country and Egypt, *viâ* Paris, may be estimated for the route by Marseilles and the route by Mont Cenis and Brindisi (the Italian railways having recently been opened for traffic to that port) respectively, as follows:

For the Marseilles route:—

Paris to Marseilles 864 kilometres, at 54 per hour...	16 hours.
Marseilles to Alexandria 1460 nautical miles, at 10 per hour, with 6 hours' delay at Malta ...	152 ,,
Total	168

For the Brindisi route, by Mont Cenis and Brindisi:—

Paris to Macon ...	441 kilometres,	at 54 per hour,		8¼ hours.
Macon to St. Michel	237 ,,	40	,,	6 ,,
St. Michel to Susa	77 ,,	18	,,	4¼ ,,
Susa to Brindisi	1159 ,,	40	,,	29 ,,
Brindisi to Alexandria	822 nautical miles,	10	,,	82¼ ,,
		Total		130

showing a saving in favour of the Mont Cenis and Brindisi route of 38 hours. This would be of importance in facilitating the communication between this country and India, and in the transmission of the Indian mail, though it is to be observed that there would necessarily be a change of vehicles at St. Michel and Susa.

The results of this experiment are of great importance to the future of railway construction in mountainous countries, as will be seen from the following observations:—

Whenever it becomes necessary to cross a chain of mountains by a line of railway, the question arises as to whether it will be more economical to pass over the summit, or to make a tunnel of greater or less length. The cost of construction, and of working the estimated traffic, being duly considered, it is necessary to determine what elevation should be reached, and what length, if any, of tunnel should be formed, according to the circumstances of each case; and the most important element in the calculation is the limit up to which steep gradients may be safely and economically worked.

Mr. Fell has shown practically that gradients of 1 in 12 to 1 in 15 may by a system of horizontal driving wheels acting upon a middle rail be substituted for 1 in 25 to 1 in 30, which have hitherto been practicable, and that sharper curves may also by this system be more safely worked. He has proved, in other words, that a railway may be constructed over a given summit of half the length that would otherwise have been necessary, and at less than two-thirds of the cost; because, although the permanent way would be more expensive, averaging, say £3000 instead of £1800 to £2000 a mile, yet, by the adoption of steeper gradients and sharper curves at critical points, cuttings or embankments may be reduced or avoided, and the works generally be more cheaply laid out. And the cost of working and maintenance would, considering the same elevation to be reached, be cheapened, as well as the cost of construction. There would be half the length of line to maintain, and the speed of the trains would be reduced. Only half the speed would, indeed, be required to reach the summit in the same time, and the same (gross) loads might be taken up by the same expenditure of power at that speed so reduced to one-half; while the adhesion of the locomotive engines being doubled with the addition of no more than a sixth to their weight, an important saving would thus be effected in the dead weights of the trains. The cost of traction, which must in taking a given (gross) load to a given height be nearly the same, would not increase so much in consequence of the saving of dead weight thus effected; and other expenses would decrease to some extent in proportion to the wear and tear and resistances incidental to a higher, but avoided at a lower, velocity.

A summit line may for these reasons be made with greater facility, in less time, and to greater advantage, than heretofore; and it will be interesting, taking the Mont Cenis as an example, to compare the cost of the tunnel line now in course of construction under that mountain with a permanent line which might be made over it. The comparison is not made here with a view to that particular case, because it may now be taken for granted that the permanent tunnel line will be completed within a certain number of years, and because the summit line projected by Messrs. Brassey & Co. is only put forward as a temporary line, to be used pending the opening of the permanent line from St. Michel to Susa; but as being important with reference to other mountain passes in the Alps and elsewhere.

The temporary line is estimated (by Mr. Brunlees, C.E.) to cost 8,000,000 francs, or £320,000, or about £6720 per mile; whereas the tunnel line will probably cost, including interest, at 6 per cent. during construction, £135,000,000 of francs, or £5,400,000, or £128,500 per mile, the latter being 68 kilometres (42 miles) in length, with a maximum gradient of 1 in 28, and a gradient through half of the grand tunnel of 1 in 35½, and an average gradient for the whole of 1 in 46; and the former being 77 kilometres (about 48 miles) in length, with a maximum gradient of 1 in 12, and an extra elevation of 2520 feet; and the time occupied between St. Michel and Susa would, including stoppages, be about 3 hours by the tunnel and 4½ hours by the summit.

The cost of a permanent and independent summit line, with a wider gauge and better curves, may be taken at £20,000 a mile, or nearly three times as much as the above temporary line; and the extra cost of working over a super-elevation of 2520 feet, based upon a traffic ten times as great as that which is carried at present over the Mont Cenis, and upon the average cost of traction (0·25 of a franc or 2½*d.* per horsepower per hour) upon the Semmering and Giovi Inclines, capitalized at 6 per cent., at £13,000 per mile. These two sums added together amount to £33,000 per mile, or rather more than one-fourth of £128,500 per mile set down above for the tunnel line.

This estimate would, of course, be materially modified by local circumstances, but it is as good an illustration as can be given at present of the advantage that may be derived, in cases in which stationary engines and inclines worked by ropes are not appropriate, from constructing railways on steeper gradients than have hitherto been considered practicable, in the manner which Mr. Fell has now shown to be available.

As the results of his observations and experiments, Captain Tyler reports in conclusion, that this scheme for crossing the Mont Cenis is, in his opinion, practicable, both mechanically and commercially, and that the passage of the mountain may thus be effected, not only with greater speed, certainty, and convenience, but also with greater safety than under the present arrangements. Few would, in the first instance, either contemplate or witness experiments upon such steep gradients, and round such sharp curves on the mountain side, without a feeling that much extra risk must be incurred, and that the consequences of a fractured coupling, or a broken tyre, or a vehicle leaving the rails, would on such a line be considerably aggravated.

But there is an element of safety in this system of locomotive working which no other railway possesses. The middle rail not only serves to enable the engine to surmount, and to draw its train up these gradients, but it also affords a means of applying any required amount of extra break-power for checking the speed, or for stopping any detached vehicles during the descent; and it further acts, by the use of horizontal guiding wheels on the different vehicles, as a most perfect safeguard, to prevent engines, carriages, or waggons from leaving the rails, in consequence either of defects in the bearing rails or of failure in any part of the rolling stock. The safest portions of the proposed railway ought indeed, under proper management, to be those on which, the gradients being steeper than 1 in 25, the middle rail will be employed.

There is no difficulty in so applying and securing that middle rail, and making it virtually one continuous bar, as to preclude the possibility of accident from its weakness or from the failure of its fastenings, and the only question to my mind is, whether it would not be desirable still further to extend its application to gradients less steep than 1 in 25. It would apparently be advantageous to do so, not only for the sake of obtaining increased adhesion with less proportional weight, and therefore economical traction, but also with a view to greater security, especially on curved portions of the line.

After going with Mr. Fell through the different calculations and considerations which are involved in the undertaking, Capt. Tyler finds that he has, during three years of labour, treated them with the utmost care and caution; and has no doubt of his being able (if Mr. Fell obtains, as he hopes to do in the course of a few weeks, the necessary authority from the French Government) to carry it forward to a successful issue. It is anticipated that in the course of the summer of 1866, in time for the autumnal stream of travellers into Italy, Mont Cenis will be traversed by rail in 4½ hours, or even less, from St. Michel to Susa, now a tedious diligence journey, on wheels or sledge, according to season, lasting more than double that time.

ANGLO-INDIAN ARCHITECTURE.

By Major J. G. Medley, R.E.

The revival of architectural taste which has sprung up within the last twenty years in England, is slowly but gradually spreading to India, and within the last few years more than one handsome church, railway station, or other public building has been erected, which would do no discredit to any European capital. This improvement has certainly not come before it was wanted. Until very lately we did not shine in designing public or private buildings at home; witness the heterogeneous rows of suburban villas in the neighbourhood of London, or the unmitigated monotony and ugliness of many of our modern streets. But we certainly surpassed ourselves in India, and succeeded in inventing a style of building, (irreverently known as the Military Board style,) which for ugliness beat everything that ever was constructed by man.

Who does not know the sense of desolation that comes over one at first sight of some of our Indian cantonments; the straight and dusty roads, the rows of glaring white rectangular barracks, the barn-like church, differing only from a barrack in the presence of a square tower and classical (!) portico, the Roman Catholic chapel ditto, only smaller and with bright green doors all round.

Then the houses, evidently built after the model of the barracks, unless when the genius of the builder had displayed itself in a profusion of bright colours on the external walls, arranged in such startling contrast that the dâk horses were very apt to shy at passing it.

If we go inside, matters are not much better. High bare white-washed walls, a barn-like roof, with perhaps a dirty ceiling cloth shaking in the wind, a dilapidated plaster floor, and square holes cut in the wall doing duty as doors and windows. One exception alone is there to this puritanical simplicity, in the fireplace, which is evidently an offspring of the genius of the native mason, and consists of a grotesque mass of ornaments, which would perhaps be more effective if unblackened by the smoke from the ill-constructed chimney.

The general reason assigned for such a state of things is—1st, The requirements of the climate; 2nd, The necessity of economy. But the cogency of either argument must be altogether denied. There can be no doubt that a thoroughly airy and well-ventilated building may be made just as ornamental as one which is adapted for a cold climate only; and that a small amount of money expended in judicious ornamentation will scarcely affect the total cost of the building. The real reason has been undoubtedly a want of taste and knowledge; and now that such deficiencies are beginning to disappear, it is hoped and believed that the beginning of an improved state of things has arrived. It must I think be allowed that the true principles of architectural construction for buildings in the East, which are to be used by men habituated to an entirely different climate, have not as yet been discovered; a mosque for instance has a pleasant temperature both in winter and summer, while a Gothic church in India is as a rule either very hot or very cold. I do not say that Gothic churches are unsuitable to India, but only that they are so as we now build them. In the same way, many of our houses with lofty rooms, numerous openings and thin walls, are far less cool and pleasant than native houses, low and badly ventilated as they are, with thick walls and few doorways. I do not say that we ought to live in native houses, but simply that we have not as yet hit upon the right way of constructing our own.

Treating of architecture as distinct from mere building, it is an art, not a science, and therefore does not fall under exact rules of instruction; one consequence of which is, that while engineering advances and improves, architecture stands still and copies. We make better roads and bridges now than in the 15th century, but we have hardly got beyond copying their churches; and until there is a reformation in this respect, it is hopeless to expect that we shall have an architecture adapted to the peculiar circumstances of Anglo-India. It is not intended here to propound any original ideas on the subject of Anglo-Indian buildings, lay or ecclesiastical, but merely to offer a few hints for improvement in matters of detail which may be useful to those called upon to design and erect buildings in India.

First, as to the style of our dwellings in the Upper Provinces. As above hinted, it is doubted whether the present style is not radically unsuitable to the climate. In a hot and damp country, especially if near the sea coast, numerous doors are certainly required by which the cool breezes may sweep through the house, and hence verandahs are necessary to shade the doors from the direct glare of the sun. But where, as in Upper India, it is necessary during the fierce dry heat of April, May, and June, to exclude the hot air altogether by night as well as by day, the fewer doors there are the better, and ventilation should be secured through the roof. In the cold weather, the paucity of doors would add much to the comfort of the house, and verandahs might perhaps be altogether dispensed with. The thin walls which now get so thoroughly baked that they continue to radiate heat by night and day for months together, should be made twice their present thickness, or better still, might be double. Upper storied buildings are perhaps more suitable to Lower than Upper India, unless the upper rooms are used solely as dormitories, but considerations of expense will generally bar their adoption. In many parts of the country perhaps the old Eastern style of building, round an open quadrangle in the centre, might be adopted with advantage. This open court paved with marble or stone, filled with fragrant shrubs, and with a fountain and tank in the centre, is characteristic of most of the dwellings of the wealthy throughout Syria and other Eastern countries, and is indeed common enough in native houses in India. Perhaps some one will work the idea into a tangible shape.

Next let us protest against the indiscriminate use of plaster, so generally applied to buildings of all kinds in India. In most cases it is simply used to conceal bad masonry, and every plastered building looks shabby in a few months after being constructed. It is expensive, and adds no strength to the work. Brick masonry if well executed has a beauty of its own, and with well-made bricks, well bonded, and with fine joints, there can be no meaning whatever in hiding the material. Some excellent specimens of brick masonry have been lately erected in Upper India, but improvement is required in the manufacture of bricks before this kind of work can be executed to the best advantage, otherwise the dressing and chipping of the surface entails much labour, and removes the outer skin of the brick, which is the most durable part and is best fitted for resisting atmospheric effects. The use of the pug-mill, a careful choice or mixture of earth, and perhaps the employment of machinery in moulding, would ensure the requisite degree of excellence. By the employment of coloured bricks in the exterior mouldings very good ornamental effects might it is believed be produced. Plaster must still be used for the interior surfaces of walls, and where the best kinds of lime plaster can be afforded, perhaps no better material can be wished than the smooth polished surface thereby produced. But if inferior plaster be used, why daub it invariably with the lime whitewash, which comes off on the clothes, and produces a most wretched and shabby effect? Wherever chalk can be obtained, it is little dearer than lime, looks much better, does not whiten your coat every time you lean against the wall, and takes the common colouring matters well. Of these the *neila tutya* (sulphate of copper), the *peoree*, *soorukh*, and *Mooltanee muttee*, are well known in Upper India; and good shades of blue or green, yellow, red, and buff, are produced from them; but let them be mixed with chalk, not lime, as is usually done, and use a sizing of glue or rice-water. There is a popular but ill-founded objection against the use of paper for walls. In a damp climate like Bengal it would not do, but in the dry Upper Provinces there is no reason whatever for not employing it.

Will somebody invent a new material for roofs in India? Slates we have not, except in one or two out-of-the-way localities. Galvanized iron we cannot get. Tiles get broken, and look ugly, and are leaky. The ordinary flat terrace roof leaks also, and is very heavy. A trussed roof with a very slight pitch (say 10°), and covered with flat bricks and lime terrace is about the best we know, but is very far from being what it should be.

But our floors are worse. A lime floor looks very well when just finished, and for a private house answers its purpose fairly; but for a building like a barrack it is soon cut up, is unhealthy, (the dusty particles flying about engender opthalmia,) and impossible to repair satisfactorily. A plank floor is expensive, perishable, and warps from the extreme changes of the climate. The best floors hitherto made are those of flat brick or brick-on-edge. But why should not this method be improved upon in public and private buildings? Excellent coloured and glazed tiles are made in the Punjab and other parts of India, and hexagonal or diamond shaped flooring tiles of white and blue or black look very well, and ought, if properly made, to wear well. The glaze is objectionable as making the floor slippery, and apt to chip or wear off, but why should we not use the unglazed encaustic tile, now employed so largely in England by Minton and other manufacturers? No better floor could be devised for a private house in the hot weather than one of coloured tiles, laid in an ornamental pattern, and which would enable us to dispense with carpet or matting. I have little doubt that, if a manufacture were started on a line of railway, the speculation would pay excellently; and I would recommend the idea to Government for the new public offices at Calcutta, Allahabad, and elsewhere. I believe the requisite materials exist in plenty throughout India, and nothing is wanted but the requisite skill and capital. One other material may be named for floors, viz., gypsum, or plaster of Paris (sulphate of lime), which abounds in some parts of India, as for instance, the Dehra Doon. It is excellently adapted for floors, cornices, and other interior parts of buildings, and is capable of being made into highly ornamental forms.

Fire-places and chimney-pieces must be left to the taste of the builder. The exceedingly ugly square upper windows may be replaced by circular ones, especially if the doors have circular fanlights above them. For both doors and windows coloured glass may be used with great advantage to the comfort of the room, and the *diaphane*, or imitation stained glass, is both economical and pretty.

Punkahs may be decidedly improved. The kind generally known as the Bombay punkah, consisting of a single bar of wood with a heavy deep fringe, is decidedly superior to the abominable white-washed rectangle which invariably disfigures every room in Upper India. But if the latter shape is preferred as giving more air, at least let it be coloured or covered with ornamental paper; let the fringe be of good material and colour, and, above all, clean; and let the ugly thick white cotton ropes be replaced by thin coloured cord or wire.

Enough has been said for the present, or we might still declaim against mud walls of compounds, ugly rows of out-houses, hideously ornamental gateways, &c. But as it is to be hoped a more refined taste is in progress, it may be sufficient to urge the subject on the attention of those whom it may concern.

THE WROUGHT-IRON ROAD BRIDGES OF THE CHARING CROSS RAILWAY.

By M. Parkes.

(*With an Engraving.*)

Before proceeding to the immediate subject of the paper, it is thought a brief sketch of the line in general will not be out of place. It is therefore intended to describe the nature of the constructions, commencing at the Charing-cross end of the line.

The line, on leaving the Charing-cross station, crosses the Thames on an iron bridge of nine spans, six of them 154 ft., and the remaining three 100 ft.* Commencing at the north end, the supporting works are as follows:—

North abutment of brickwork, with stone beds for girders; first pier consists of nine cast-iron cylinders 10 ft. in diameter at bottom, diminishing to 8 ft. and 6 ft. diameter in the case of the two outside and seven inside cylinders respectively. These cylinders are merely filled with concrete up to 5 ft. above Trinity high-water mark; the lower edge of cylinders being about 6 ft. in the London clay, and are surmounted by a cast-iron bed-plate 18 in. deep. Second pier: this is similar to the preceding, excepting that there are only five inside cylinders. Third pier: north tower of suspension bridge altered. Fourth, fifth, and sixth piers each consist of two cast-iron cylinders, 14 ft. diameter at bottom, reduced by a diminishing ring to 10 ft. diameter at low water; the lower edge of the cylinders being from 15 ft. to 20 ft. in the London clay. The cylinders are filled with concrete up to 9 ft. below low-water, the remainder being brickwork, finally surmounted by granite blocks, 2 ft. 6 in. deep, in semicircles. Seventh pier: south tower of suspension bridge altered. Eighth pier, the same as fourth, fifth, and sixth. South abutment, of brickwork with stone quoins and cornice, bed stones for girders of granite 2 ft. 6 in. deep.

The bridge is 46 ft. 4 in. wide in the clear, from the south abutment to the third pier; it then widens out, till, at the north abutment, it is 164 ft. wide. The six 154 ft. spans constitute the "parallel section" of the bridge, and the three 100 ft. the "fan section." Each of the 154 ft. spans consists, mainly, of two trusses, 11 ft. 6 in. deep centre to centre of pins, and each weighing 190 tons, and of fifteen lattice cross girders, 4 ft. deep at centre, and each weighing 8½ tons. Each of the 100 ft. spans consists of two light trusses, so as to preserve an uniform sky line, and ten, seventeen, or twenty-four girders of 5 ft. deep, according to the position of the span. The weight of the trusses is 40 tons each, and of each of the 5 ft. girders 27 tons. This section of the bridge is covered over with 6 in. planking. There is a footpath on either side of the bridge, which is carried on lattice cantilevers riveted to the cross girders on the 154 ft. spans, and to the cross girders connecting the exterior shallow girders with light trusses on the 100 ft. spans. This bridge has four lines of way between the southern abutment and the third pier.

From the south bank of Thames to Belvedere-road, the line is carried on ten brick arches, 30 ft. span. On plan, this section of brickwork is of a fan shape, being wide enough between parapets at the river-end to accommodate coke-stand, water-tank and crane, and turntable, besides four lines of way; at the Belvedere-road end, there is something to spare over the usual allowance for three lines. These arches, which are formed of five rings, have a rise of 7 ft. The piers, from which two adjoining arches spring, are 4 ft. wide, and pierced with one or more 10 ft. jack-arches, according to the length. The parapet walls are 5 ft. 9 in. high above string-courses, 14 in. thick, and surmounted by a cope-stone 16 in. by 5 in.

The Belvedere-road is crossed by an iron bridge, consisting of six inner working girders, and two face girders with a light parapet riveted to upper flange; the span is 46 ft. and the depth of the girders 3 ft. 6 in.

From Belvedere-road to Sutton-street, there are four 30 ft.

* The bridge above referred to, called the "Charing Cross Bridge," was illustrated and described in this Journal, vol. xxvii. (1864), p. 219, 267, and 300.

arches, and, excepting that the clear width between parapets is 35 ft. 8 in., they are similar to those previously described, and to all other 30 ft. arches on the line.

Sutton-street is crossed at an angle of 25 degs. by an iron bridge, consisting of two main box girders, 7 ft. 8 in. deep at centre, having cross girders 2 ft. deep, riveted to their bottom flanges, for forming platform of bridge.

The line is then carried on two 30 ft. arches till it reaches the York-road, which is crossed, at a slight angle, by a bridge consisting of two single web girders, 7 ft. 6 in. deep, 70 ft. span—cross girders, 16 in. deep, being riveted to their lower flanges.

The line then proceeds in a curved direction, on seven 30 ft. arches, till Vine-street is reached, which is crossed by a bridge similar to that over Belvedere-road, excepting that the span on skew is 51 ft. Between Vine-street and Waterloo-road there is a triangular abutment, pierced with a 10 ft. arch. The apex of the triangle is at the junction of the road and street, and the walls, which form the legs, are provided with stone girder beds for the two bridges respectively. A box girder bridge, similar to that over Sutton-street, crosses the Waterloo-road at an angle of 50 degs. The span on skew 110 ft., the depth of girders at centre being 11 ft. 8 in., and the clear width of the bridge is 40 ft. 6 in., to allow for curve of line. Between Waterloo-road and John-street there is a triangular abutment, similar to that just mentioned, excepting that the angle at apex is made more obtuse. The bridge over John-street crosses it at so great a skew, that no cross girder is connected to both main girders. These main girders are similar to those at York-road; the lengths over all are 96 ft. 4 in. and 89 ft. 6 in. respectively, with a central depth, in each case, of 7 ft. A little beyond John-street bridge, there is a short branch connecting the Charing-cross with the London and South-Western Railway. The branch comprises two 30 ft. arches, and an iron bridge crossing the Waterloo-road about 200 ft. from the main line bridge. There is only width for two lines on this branch. The wrought-iron bridge is 77 ft. span, and consists of two main girders, similar to York-road, 6 ft. 6 in. deep at centre; cross girders, 16 in. deep, are riveted to bottom flanges.

Returning to the main line, from John-street the line is carried over six 30 ft. arches till it reaches Cornwall-road, which is spanned by a 40 ft. brick arch of six rings; thence there is a series of twenty-two 30 ft. arches, terminating at Broadwall, over which the line is carried by an iron bridge similar to Belvedere-road. The span of this bridge is 41 ft., and the depth of girders 2 ft. 6 in.

From Broadwall the line is carried on ten 30 ft. arches to the Blackfriars-road, where there is a box girder bridge of 100 ft. span. Between this bridge and the Southwark Bridge-road, which is the site of the next iron bridge there is a section of brick viaduct, consisting of fifty-two 30 ft. arches. The iron bridge is of the box type, and is similar to the others, excepting in the unequal lengths of the main girders; 135 ft. and 83 ft. being the respective lengths. The line is then continued by eleven 30 ft. arches to Southwark-street, the junction of the City extension. From Belvedere-road to this point there are three lines of way; at Blackfriars-road, on the London Bridge side, the brick constructions are extended laterally for station accommodation.

Returning to Southwark-street, this is spanned by a bridge of two bowstring girders, 150 ft. long, and placed 56 ft. apart, between flanges. Cross girders are riveted and bolted to the under side of "tie" for receiving roadway plates and permanent way. The abutment at the Charing-cross end of bridge is pierced by a 30 ft. arch, which spans Redcross-street; the other abutment is spanned by two 10 ft. arches.

From Southwark-street to York-street included there are only two lines. This portion of the main line may be divided into three sections, as follows:—

First section from Southwark-street to Counter-street, consisting of nine 30 ft. arches; second section, which is an iron viaduct carried on fifteen cast-iron columns through the Borough Market; and the third section, a bridge over York-street, consisting of four inner and two face girders, varying in length from 44 ft. to 47 ft., and 3 ft. deep; parapet 6 ft. high, of sheet iron.

Adjoining York-street bridge, at the eastern end, is another viaduct through the Borough Market. This viaduct, the site of the Eastern Junction of the City Extension, is in three spans of 45 ft., the supporting works consisting of two brick abutments, and two piers of five and four columns respectively. These columns are surmounted by a box girder, which forms a bed for the longitudinal girders, as will be explained in a subsequent part of the paper. The line, on leaving the viaduct just referred to, passes on a small piece of brick viaduct, consisting of one 20 ft., one 15 ft. and one 10 ft. arch, to Wellington-street, which it crosses by an iron bridge. This bridge is of the single web type, 118 ft. span on skew, and 36 ft. 6 in. clear width, to allow for the curve of line, which is here 10 chains.

Between Wellington-street and the South-Eastern incline is St. Thomas's viaduct, formed by one 30 ft. arch, and a V-shaped opening on either side, spanned by wrought-iron girders. The incline is crossed by a wrought-iron box girder bridge; the main girders, elliptical in shape, are 207 ft. and 176 ft. long respectively. In this bridge the main girders are not parallel with each other, being 44 ft. 4 in. between flanges at the Duke-street end, and 38 ft. at the St. Thomas's end. The curve of line on this bridge is about the same as on Wellington-street. Between the bridge over the incline and the last wrought-iron bridge on the line—namely, that over Joiner-street—there is a short section of brick viaduct, also on a curve, and comprising one 20 ft. and four 25 ft. arches. As previously stated, the Joiner-street bridge is situated at the opposite end of this viaduct to the incline bridge, and, like it, consists of two main girders of unequal length, and not parallel with each other. The main girders are of the single web type, and 70 ft. and 52 ft. long respectively: the depth of the girders is 5 ft. 6 in.; the top chord is parallel to the bottom, and has a sheet-iron screen, 2 ft. high, riveted to it. On crossing this bridge, the down-line platform of the London Bridge Station is reached, a point at which the works may be regarded more as a lateral extension of the South Eastern works, than independent structures; it is therefore not thought necessary to continue this introductory sketch any further, but to pass on to the detailed descriptions of the wrought-iron structures.

In writing this paper, the object of the author is simply to make known the proportions of existing works; as they are established facts fulfilling certain conditions, which enables a comparison of them to be made with any intended structure, in accordance with the principles of the mechanism of bridge construction.

In all the bridges on this line, a clear roadway the full width of the bridge has been secured. Excepting the Borough-market viaduct, this has been obtained by the two following methods: 1st. In the case of spans up to, say 50 ft. by placing shallow girders immediately under the rails for the working girders; the two face girders, which have riveted to their upper flanges a sheet-iron parapet, being of lighter section. Plate 25, Figs. 1, 2, 3, 4 and 5, is an illustration of this type of bridge. 2nd. In the case of larger spans, the roadway has been formed by attaching cross girders to two main girders, as shown in Plate 25, Figs. 6 to 13.

The following are the three systems of road-plating employed: 1st. For the small spans, wrought-iron arch-plates, ¼ in. thick, are riveted to the top flanges of the girders. Plate 25, Fig. 1. 2nd. For the larger spans, when the line is straight, longitudinal plates 16 in. × ¼ in., centred with the rails, extend from end to end of bridge: they are riveted to the cross girders; then, arch-plates, ¼ in. thick, are riveted to their sides. Angle-irons, 3½ × 2½ × ⅜ are substituted for the longitudinal plates at the sides of the bridge. Plate 25, Fig. 13. 3rd. For the preceding case, when the line curves, the cross girder has riveted to its upper flange a ½ in. plate, 5 in. wider than flange, and centred with it. The space between two cross girders is then filled in with flat plates, ¼ in. thick, riveted to plates on upper flanges of cross girders. Plate 25, Figs. 6 and 8.

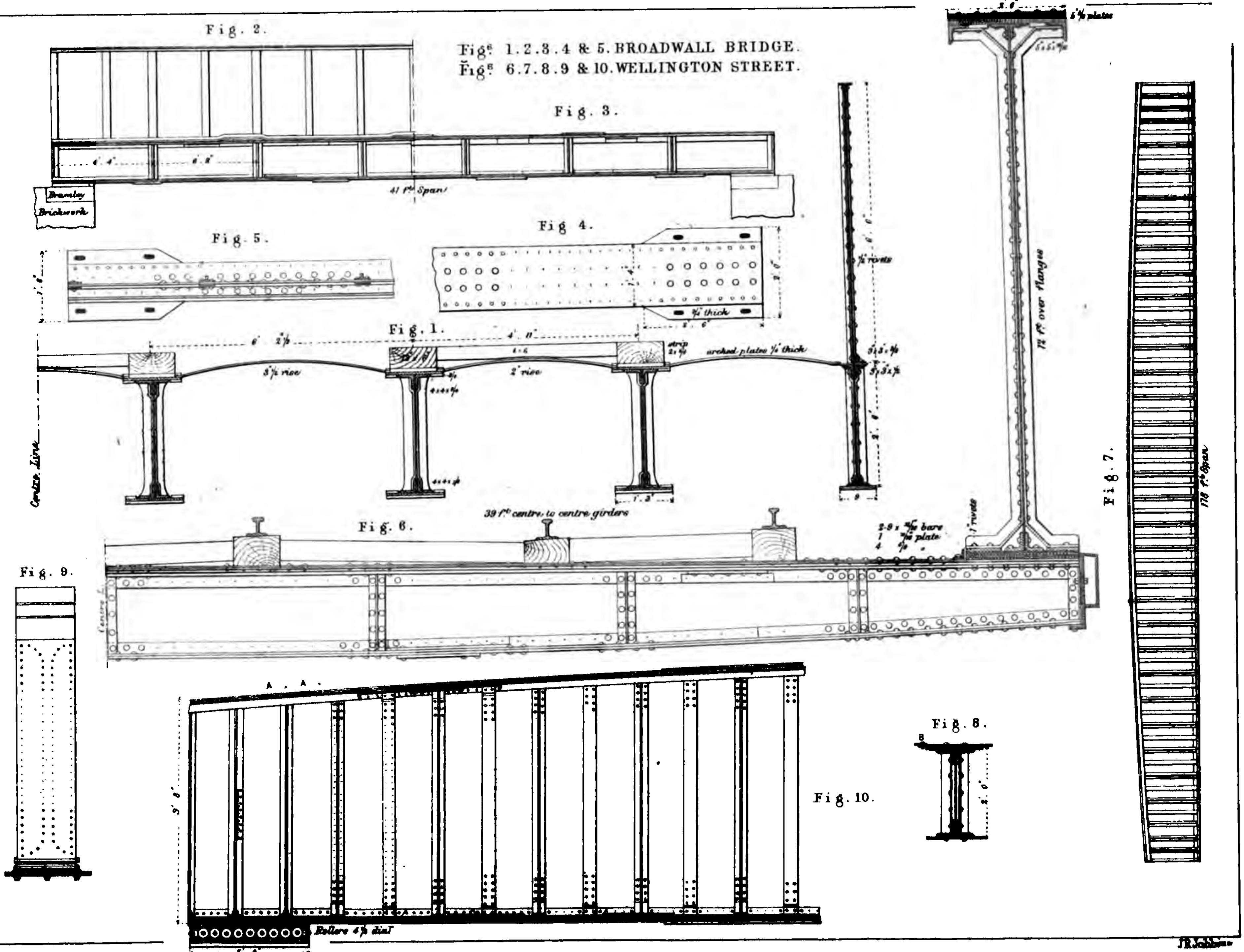
There have been three types of structure employed, namely, the single web girder, the box girder, and the bowstring girder. To avoid tedious repetition, the bridges of each type have been classed, and the details for the bridges of the same class given consecutively.

The first bridges that have been classed together are, Belvedere-road, Vine-street, York-street, and Broadwall. The spans and depths of girders are as follows:—

Belvedere-road . . .	46 ft. span,	3 ft.	6 in.	deep.
Vine-street	51 ,,	3	6	,,
York-street	37 ,,	3	0	,,
Broadwall	41 ,,	2	6	,,

These bridges being so similar, it is thought sufficient to describe two only—namely, Vine-street and Broadwall.

Vine-street.—This bridge accommodates three lines of way, as


Figs 1.2.3.4 & 5. BROADWALL BRIDGE.
Figs 6.7.8.9 & 10. WELLINGTON STREET.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
41 ft Span
Bramley
Brickwork
Centre Line
arched plates ½ thick
2" rise
39 ft centre to centre girders
72 ft over flanges
178 ft Span
Rollers 4½ dia.
½ rivets
1" rivets

J.R. Jobbins

consists of six working and two face girders. In Plate 1, Fig. 1 is a half-section of a bridge, 41 ft. span; Fig. 2 is a half-elevation of a face girder; Fig. 3 is a half-elevation of a working girder; and Figs. 4 and 5 are plans of ends of a working and a face girder respectively. The dimensions of the working girders are as follows:—Top flange, two plates $\frac{7}{16}$ in. thick, 20 in. and 16 in. wide: the former is uppermost, and is prepared to receive the roadway plates; bottom flange, 16 in. wide by $\frac{3}{4}$ in. thick; web, $\frac{1}{4}$ in. thick, stiffened by having the vertical joints connected by two T irons, 5 in.×2½ in.×½ in. Rivets $\frac{3}{4}$ in. diameter, and 4 in. pitch. Each flange is connected to the web by two angle-irons 4 in.×4 in.×$\frac{5}{8}$ in. At each end there is a bearing-plate, 2 ft 6 in.×2 ft.×$\frac{3}{4}$ in., pierced with oblong holes to suit four Lewis's bolts 1 in. diameter.

For the face girders, the following are the dimensions: Top flange, 11 in. wide by $\frac{1}{2}$ in. thick, not centred with web, but 1 in. out: this is to provide for attaching the roadway plates; bottom flange, 9 in. wide by $\frac{1}{2}$ in. thick; web, $\frac{1}{4}$ in. thick, connected to each flange by two angle-irons, 4 in.×4 in.×½ in. The webs are stiffened in the same manner as the working girders. The roadway is formed of arch plates, $\frac{1}{4}$ in. thick, with a rise of about 3 in., and riveted with $\frac{1}{2}$ in. rivets, 4 in. apart, to top flanges of girders. On the top flanges of the working girders longitudinal timbers, 16 in. wide by 6 in. and 9 in. thick, for the lower and higher rail respectively, are placed: each pair of timbers are framed together by a transom and 1 in. bolt every 6 ft. The transoms are shown in Plate 1, Fig. 1.

For forming the parapets, an angle-iron, 3 in.×3 in.×$\frac{3}{8}$ in., is riveted to the top flanges of the face girders, by the same rivets that attach top flange to the 4×4×½ angle-iron. To this angle-iron, plates three-sixteenths thick are riveted. They are 6 ft. high, and of such a width, that a vertical joint occurs over each pair of tee irons of the face girders, and one between any two pairs. The vertical joints are stiffened by a tee iron, 4×2×$\frac{3}{8}$ inside, and a strip 4 in.×½ in. outside. The top rail is of tee iron, the same section as the vertical ones. The rivets in roadway and parapet are the same.

The clear width between parapets is 36 ft. 4 in., which allows for the curve of the line at this point. The weight of the eight girders is 38 tons 14 cwt.; and the whole weight of the bridge 50 tons 14 cwt.

Broadwall.—This bridge also consists of six working and two face girders. The dimensions are as follows: for working girders —Top flange, 16 in. wide by $\frac{3}{4}$ in. thick, riveted to web by two angle-irons, 4 in.×4 in.×$\frac{3}{4}$ in., and pierced with holes for $\frac{5}{8}$ rivets every 3 in. on each side; bottom flange, 15 in. wide by $\frac{3}{4}$ in. thick, riveted to web by two angle-irons 4 in.×4 in.×$\frac{5}{8}$ in.; web, ½ in. thick in seven sections, connected at vertical joints by two tee irons, 5×2½×$\frac{5}{8}$. At each end of girder there is a bearing-plate of the same dimensions as in Vine-street bridge. For face girder —Top flange, 9 in. wide by ½ in. thick, not centred with web, to which it is connected by two angle-irons 3×3×½. The webs are the same as for working girders, and the parapet similar to Vine-street.

The girders in this bridge are braced by a system of diagonal bars, 3 in×$\frac{5}{8}$ in., connected to girders by means of short pieces of tee iron, riveted to top and bottom of webs about 6 ft. 8 in. apart. The road-plating is similar to that for Vine-street. In addition to the ordinary angle-iron cover, a strip is riveted to the opposite side of the girder. The weight of the six working girders is 26½ tons; of the two face girders, 4$\frac{3}{4}$ tons; and of the whole bridge, 43 tons.

The next class of bridge that it is intended to describe are those in which the roadway is formed by cross girders attached to two main girders of the single web type. There are five bridges of this class—namely, York-road, John-street, Waterloo Branch, Wellington-street, and Joiner-street. The preceding is the order it is intended to describe them in. Plate 1, Figs. 6 to 10, is an illustration of a bridge of this type, 118 ft. span. Fig. 6 is a half transverse section of the bridge to a 3 in. scale; Fig. 7, an elevation of one of the main girders to a $\frac{3}{8}$ in. scale; Fig. 10, an elevation of end of main girder to a 1½ in. scale; Fig. 9, an end elevation of main girder to the same scale; and Fig 8, a transverse section of cross girder to a 3 in. scale.

York Road Bridge.—Main girders, 82 ft. 3 in. and 80 ft. 3 in. long; they are similar in other respects, and of the following dimensions: Depth at centre; 7 ft. 6 in., at ends, 6 ft.; top flange, 2 ft. 2 in. wide, consists of four $\frac{5}{8}$ plates at centre, reduced to three plates at ends; bottom flange, 2 ft. wide, consists of one $\frac{3}{4}$ and three $\frac{5}{8}$ plates at centre, reduced at ends to one $\frac{3}{4}$ and two $\frac{5}{8}$. Both flanges are connected to web by means of two angle-irons, 6×6×$\frac{3}{4}$. The two web plates at either end are 2 ft. and 2 ft. 4 in. wide, and the remainder 3 ft. wide. Five plates at either end are $\frac{5}{8}$, and the remainder ½ thick; the vertical joints are connected by two tee iron gussets, 6 in.×3 in.×$\frac{5}{8}$ in., except at the end joints, where four angle-irons, 3×3×$\frac{5}{8}$, and two ½ in. gusset-plates are substituted for the tee irons. Riveting, all vertical, 1 in. diameter; all others, $\frac{7}{8}$ diameter.

Cross Girders.—Those connected to both main girders—the bridge being on a skew—are 39 ft. long by 16 in. deep; they are all placed 3 ft. centre to centre. Each flange is 15 in. wide by $\frac{3}{4}$ in. thick, connected to web, ½ thick, by two angle-irons, 5 in.× 3 in.×$\frac{5}{8}$ in. The web is divided by vertical T irons into four panels. The road plating is on the second system, as shown in Plate 1, Fig. 13. One end of each main girder rests on eight rollers, 4½ in. diameter. The weight of the two main girders is 49 tons 16 cwt., and the whole weight of bridge is 141 tons 13 cwt.

John-street.—As previously stated, this bridge is on a great skew, the bridge on plan being of a lozenge shape. The main girders are 96 ft. 4 in. and 89 ft. 6 in. long respectively; the depth at centre 7 ft.; at ends 6 ft. Both flanges are 2 ft. wide; the top is built up of four nine-sixteenths plates at centre, reduced to three plates at ends; the bottom is built up of one eleven-sixteenths and three nine-sixteenths plates at centre, reduced to one nine-sixteenths plate less at ends. The end web plates are 2 ft. 4 in. wide, and the remainder 3 ft. Five plates at either end are $\frac{5}{8}$, and the remainder ½ thick. The vertical joints are connected by T irons, the same as York-road bridge, and the horizontal by angle-irons, 6 in.×6 in.×$\frac{3}{4}$ in. The cross girders are all 2 ft. deep, but varying in section to suit the length: they are placed 4 ft. apart, centre to centre, and the spaces between them filled in with road-plating, on the third system shown in Figs. 6 and 8. Rollers are provided at one end of each main girder, as in York-road bridge. The weights of the longer and shorter main girders are 24 tons 13 cwt. and 23 tons 3 cwt.; of the cross girders, 52 tons; and the total weight of bridge, 124 tons 7 cwt.

Waterloo Branch Bridge.—This is for two lines only; the lengths of main girders are 86 ft. and 84 ft.; the depths at centre and ends, 6 ft. 6 in. and 5 ft. 3 in. Flanges 2 ft. wide, the bottom built up of one $\frac{3}{4}$ and three $\frac{5}{8}$ plates at centre, and one $\frac{3}{4}$ and two $\frac{5}{8}$ plates at end; the top flange is built up of four $\frac{5}{8}$ plates at centre, reduced to three at ends. Two angle-irons, 6×6×$\frac{3}{4}$, connect each flange to webs, which are disposed in the same way as in York-road bridge. The cross girders are placed 4 ft. apart centre to centre; they are 16 in. deep, and consist of a ½ web with two angle-irons, 4×4×$\frac{3}{4}$, riveted top and bottom for flanges. The length of the girder is divided into three panels by vertical T irons. The roadway is of the second system. Plate 29, Fig. 13.

Under one end of each main girder, eight rollers, 4½ in. diameter, are placed; the upper and lower plates for these to work between are of cast-iron, 2 in. thick; the frames are of wrought-iron, 3 in.×1 in. The fixed ends are provided with bearing-plates $\frac{3}{4}$ in. thick. The weight of the two main girders is 49½ tons; of the cross girders, 24 tons 16 cwt.; and of the whole bridge, 94 tons.

Wellington-street Bridge.—This is the largest single web girder bridge on the line, the length of the girders being 134 ft., and the span on skew 118 ft. The girders are 12 ft. deep at centre, and 9 ft. 8 in. at ends.

The flanges are 2 ft. 6 in. wide, riveted with six rows of 1 in. rivets. The top flange is built up of five $\frac{5}{8}$ plates at centre, reduced to three at ends. In addition to the two angle-irons which connect this flange to web, there are two other of the same size, 5×5×$\frac{11}{16}$, riveted to each edge. Plate 25, Fig. 6. The bottom flange is built up of one $\frac{11}{16}$ and four $\frac{5}{8}$ plates, reduced at ends to one $\frac{11}{16}$ and two $\frac{5}{8}$ plates. On each side of the upper side of this flange a bar, 9 in.×$\frac{11}{16}$ is riveted. This is shown in Figs. 6 and 10. Fig 10 shows the way the plates break joint. The web-plates, with the exception of the end ones are 2 ft. 2 in. wide, the end ones being 2 ft. wide, as shown in Fig. 10; $\frac{5}{8}$ thick for a length of nine plates at either end, and five-sixteenths for the remaining distance.

Referring to Figs. 7, 9, and 10, it will be seen that a ½ plate is riveted to the ends of the girders by means of angle-iron gussets, 3 in.×3 in.×$\frac{5}{8}$ in.; also, that at the two end web joints ½ gusset plates are riveted, with similar angle-irons. After the bridge was erected, it was found necessary to stiffen the ends of the girders by attaching reverse angle-irons, 3×3×½, to the end and gusset plates. The intermediate vertical joints of web are connected by two tee iron gussets, 6×3×⅝, and two strips, 6×⅝, alternately. These strips, as shown in Fig. 3, are cranked to set over the longitudinal angle-irons.

One end of each girder was provided with a bearing-plate, 5 ft.×4 ft.×¾; the other end had attached to it a cast-iron plate, 2 in. thick, to bear on eight rollers, 4½ in. diameter. The roller-beds are also of cast-iron, 2 in. thick, and further strengthened by having three ribs 3 in. deep cast on; the roller frames are of wrought-iron, 3 in.×1 in. A longitudinal section of this roller arrangement is shown in Fig. 10, and a transverse section in Fig. 9.

In Fig. 10, the lengths of top and bottom angle covers are shown by the number of rivets in each. The first have 7 and 8 holes in each arm respectively, and the second 9 and 10; so that, since the rivets are 4 in. pitch, the lengths are 2 ft. 8 in. and 3 ft. 4 in. The ordinary lengths of

Angle-bars	13 ft.
Flat bars, 9×1½	17 ft. 4 in.
Joints to ditto	3 ft. 4 in.
Laminated plates	6 ft. 8 in.

The dimensions A A, Fig. 10, are 16 in. each, so that they contain four rivets in the direction of length of girder each. Considering one plate only, since there are six rows of rivets, we have an aggregate of twenty-four 1 in. rivets, or a sectional area of 18·84 square inches, against 14·76 square inches, the sectional area of a bottom plate through a line of rivet holes; or an excess in area of rivets of 4·08 square inches.

The cross girders are 41 ft. 6 in. long, which makes the distance, centre to centre, of main girders 39 ft. The distance, centre to centre, of the cross-girders themselves, is 4 ft. They have a central and end depth of 2 ft. and 1 ft. 4 in.; the flanges are 15 in.×½, connected to a ½ web by 4×4×⅝ angle-iron. The top flange has also riveted to it an extra plate, 19×½, for attaching roadway plate. Fig. 8 is a section of one of the girders, showing a road-plate attached at B. The length of the girder is divided into eight panels by vertical T irons at joints, 5×2½×⅝.

At each end of the bridge there are also shorter cross girders; but, as they are the same as a 41 ft. 6 in. girder, with a piece cut off one end, nothing more need be said about them. The ends of the cross girders are riveted to the mains with 24 rivets, 1 in. diameter. To the ends of the cross girder, a cast-iron cornice C, Fig 6, is bolted. The rivets through longitudinal angle-irons and webs are 1 in. diameter, and through vertical T irons and strips, and webs only ⅞ in. diameter. The weight of each main girder is 65 tons; of all the cross girders, 80 tons; and of the whole bridge, 248 tons.

Joiner-street is spanned by two main girders, 70 ft. and 52 ft. long, supporting fifteen cross girders, which form the platform of bridge. The main girders are not placed parallel; the length of the longer cross girder connected to both being 51 ft. 6 in., and the shorter 47 ft. 4 in. In both main girders the top and bottom flanges are parallel to each other; the central depth is 5 ft. 6 in., and the width of flanges 2 ft.

In the 70 ft. girder the flanges are built up of five ⅝ plates at centre, reduced to three at ends; in the 52 ft. girder they are built up of four ⅝ plates at centre, reduced also to three at ends. In all cases the flanges are connected to the web by two angle-irons 6 in.×6 in.×1 in. The vertical joints of webs are connected by two T iron gussets, 6×3×⅝. One end of each main girder is provided with a bearing-plate; the other bears on rollers 4½ in. diameter. The 70 ft. is provided with nine, and the 52 ft. with seven rollers; to the top flanges of both a light screen, 2 ft. high, is attached by angle-iron, 3×3×⅜, which consists of a three-sixteenths web, with top and vertical tee irons, 4×2×⅜.

The cross girders, placed 4 ft. apart, centre to centre, are 2 ft. 6 in. deep at centre, and 1 ft. 3 in. at ends. The flanges, 16 in. wide by ¾ in. thick, are each connected to the ½ web by two angle-irons, 4×4×⅝; the top flange has ½ plate riveted to it, as shown in Fig. 8. In the main girders, all vertical rivets are 1 in., and the horizontals ⅞ in.; in cross girders, all ⅞ in. The weight of 70 ft. girder, 21½ tons; of the 52 ft. girder, 14½ tons; of all the cross girders, 63 tons 13 cwt.; and of the whole bridge, 115 tons 12 cwt.

(To be continued.)

SUGGESTIONS ON DRAINAGE WORKS AND WATER SUPPLY.

By Robert Rawlinson, C.E.

A valuable collection of instructions and suggestions relative to sewers, drains, and water works has recently been issued by Mr. Robert Rawlinson, one of the Government engineers. Local surveyors, contractors, and others engaged on works of this nature, intended to undergo Government inspection, will find them very useful for reference. The rules and suggestions are as follows:—

Before a scheme of sewerage is devised, the district should be fully examined, so as to obtain a correct idea of the drainage area, or the several drainage areas; inquiry should then be made to ascertain how surface water has passed off up to the time of such examination, and with what effects. Main sewers and drains should be adapted to the town area, length of streets, number of houses, surface area of house yards and roofs, number of street gulleys, and volume of water supply.

Sewers and drains, in wet subsoil, should be made to act as land drains.

The following rules are general; each surveyor must, however, use his own judgment, and make the best arrangements possible under the circumstances with each special area, and with the materials at command:—

1. Natural streams should not be arched over to form main sewers.

2. Valley lines and natural streams may be improved, so as to remove more readily surface water and extreme falls of rain.

3. Main sewers need not be of capacity to contain flood water of the area drained; such flood water may be passed over the surface, in most cases without causing injury.

4. Main sewers should be laid out in straight lines and true gradients, from point to point, with manholes, flushing and ventilating arrangements at each principal change of line and gradient. All manholes should be brought up to the surface of the road or street to allow of inspection, and should be finished with a cover easily removable.

5. Duplicate systems of sewers are not required. Drains to natural streams in valley lines for storm waters may be retained, and may be improved, or if necessary, enlarged.

6. Earthenware pipes make good sewers and drains up to their capacity. Pipes must be truly laid, and securely jointed. In ordinary ground they may be jointed with clay. In sandy ground special means must be used to prevent sand washing in at the joints.

7. Brick sewers ought to be formed with bricks moulded to the radii.

8. Brick sewers should in all cases be set in hydraulic mortar, or in cement. In no case should any sewer be formed with bricks set dry, to be subsequently grouted.

9. Main sewers may have flood-water overflows wherever practicable, to prevent such sewers being choked during thunder-storms or heavy rains.

10. Sewers should not join at right angles. Tributary sewers should deliver sewage in the direction of the mainflow.

11. Sewers and drains, at junctions and curves, should have extra fall to compensate for friction.

12. Sewers of unequal sectional diameters should not join with level inverts, but the lesser or tributary sewer should have a fall into the main at least equal to the difference in the sectional diameter.

13. Earthenware pipes of equal diameters should not be laid as branches or tributaries—that is, 9 in. leading into 9 in., or 6 in. into 6 in., but a lesser pipe should be joined on to the greater, as 6 in. to 9 in., 12 in. to 15 in., 9 in. to 12 in.

14. House drains should not pass direct from sewers to the inside of houses, but all drains should end at an outside wall. House drains, sink pipes, and soil pipes should have means of external ventilation. The largest block of buildings may have every sewer outside of the main walls. No foul water drains nor cesspit should be formed beneath any house basement. All fluid refuse should pass at once from the drains to the sewers and from the sewers to the outlet.

15. Sinks and water-closets should be against external walls, so that the refuse water or soil may be discharged into a drain outside the main wall. Down spouts may be used for ventilation, care being taken that the head of such spout is not near a window. Water-closets, if fixed within houses, and having no means of direct daylight and external air ventilation, are liable to become nuisances, and may be injurious to health.

16. Inlets to all pipe-drains should be properly protected.

17. Side-junctions should be provided in all sewers and drains. The position should be sketched, and indicated by figures in a book or on a plan. Side-junctions not used at once, should be carefully closed for subsequent use.

18. A record should be kept by the surveyor of the character of the subsoil opened out in each street sewered or drained.

19. Sewers and drains should be set out true in line and in gradient. All the materials used should be sound, and the workmanship should be carefully attended to.

20. Sight-rails should be put up in each street before the ground is

opened out, showing the centre line of each sewer and depth to the invert.

21. Sewers having steep gradients should have full means for ventilation at the highest points.

22. Tall chimneys may be used with advantage for sewer and drain ventilation, if the owners will allow a connection to be made.

23. Sewers outlet-works should be simple in form, cheap in construction, and so arranged as to remove all solids, sediment, and flocculent matter from the sewage.

In executing town sewers and drains, danger may be anticipated from several conditions, as under:—

Where a street or place is narrow, with buildings on both sides, and where the trench is deep; where the substrata is clay or marl, made ground, loose earth, bog and silt, quicksand, or any combination of such strata.

Quicksand is the most difficult to deal with, and as a rule such ground should only be open in short lengths; this ground may require to be close timbered, and in such case, stable litter and ashes will be found useful to pack behind and betwixt the polling boards.

Sound looking clay or marl may require careful timbering to prevent heavy breakings from the sides of the trench. When such ground "sets" heavily, the sewer, if of bricks, may be seriously injured; if of earthenware pipes it may be ruined by cracking, or by crushing and distorting the line of sewer or drain pipes.

As a rule, all sewer and drain trenches in towns should be carefully timbered, and such timbering must either be left in, or be most carefully removed as the trench is filled.

The houses and buildings in narrow streets may require to be propped and stayed; if so, such props and stays ought not to be removed until the sewer or drain has been completed, and the ground become perfectly consolidated.

In many cases it will be cheaper, because safer, to leave timbering in deep trenches and where there is special danger the trench may be filled with concrete.

A foreman in charge of sewer works is expected to be on the watch to see that the men execute the work safely. The local surveyor must see that timber sufficient in quantity and quality is supplied to secure all open trenches, and the buildings on either side.

Where ground is known to be specially dangerous all available precautions must be taken to prevent accidents.

It is of the utmost importance to impress upon local surveyors the necessity of care in setting out main sewerage works and house drains with accuracy, in choosing sound materials, and in properly superintending the works during their progress. House drains should be so arranged as to be capable of removing all water, soil, and fluid refuse from yards, roofs, and interiors of houses to the sewers, without any risk of gaseous contamination to such houses.

Street sewers should be capable of conveying all sewage to some common outlet, without retaining sediment in them. All sewers and drains should have arrangements for full ventilation at such points and in such manner as not to cause any nuisance. Charcoal (as proposed by Dr. John Stenhouse) may be used to filter and disinfect sewage gases at all manholes and other ventilators.

If the fluid sewage can be applied to land for agricultural uses, means should be provided for effecting this purpose.

Water-closets should have a daylight window (not a "borrowed light") and fixed means for ventilation, which can neither be seen nor be tampered with. Permanent openings, equal to a slit of 12 inches in length and 1 inch wide should be provided. The cover or lid of the seat should be made to close and leave the valve handle free, so that the contents of the closet may be discharged with the lid closed down. At all times when a water-closet is not in use the lid or cover should be closed.

Water Supply.

Where a district is to be supplied with water, all other things being equal, the softest and purest water should be adopted.

A water supply may be gravitating; or the water may be pumped by steam-power. The relative economy of one or the other form of works will depend on details of cost and quality of water. As a rule, gravitating works require the largest capital. The annual working expenses of a pumping scheme will frequently be greatest.

1. Plans and sections of the proposed gathering-ground of any storage reservoir, geologically coloured, should be produced on a scale not less than 6 inches to the mile.

2. The area of the gathering-grounds proposed to be affected should be given in statute acres.

3. Plan of storage reservoir and works immediately connected therewith must be at a scale not less than 4 chains to the inch.

4. The fall of rain in the district, for not less than seven years, ought to be produced.

5. Trial shafts shall be sunk in the centre line of the site of the proposed embankment, at distances not greater than 100 feet apart. The results and details relative to the stratification obtained from such trial shafts shall also be produced.

6. Plans of the proposed outlet and other works, in detail, at a scale of not less than 20 feet to 1 inch must be prepared. Such details should exhibit the embankment in plan; and also cross sections at the deepest part of the proposed embankment. The following detail drawings shall also show—

a. Top bank width of embankment.
b. Inner and outer slope of bank.
c. Puddle-wall and puddle-trench.
d. Relative level of by-wash below top-bank level.
e. Outlet works.
f. By-wash and by-wash conduit.

7. The capacity of the reservoir, to the level of the by-wash, to be stated in cube feet.

8. No puddle wall shall be less in width at the top water line, in any part of the embankment, than 8 feet, and shall increase for each foot of vertical height not less than 1 inch in width on each side of such puddle wall, down to the ground-line at the deepest part of the embankment. Similar proportions shall be preserved throughout the entire line of the puddle wall. The puddle trench shall be filled entirely with puddle.

9. The inner slope to an embankment shall not be less than three horizontal to one vertical. The outer slope shall not be less than two and half horizontal to one vertical. Embankments should be formed in layers of earth not more than 12 inches deep, spread evenly over the entire area of such embankment; neither railways nor tramways should be used on a waterworks embankment, but dobbin-carts or wheelbarrows. An embankment should be formed evenly and regularly, the puddle wall and the rest of the bank being brought up simultaneously.

10. The finished top-bank width of any reservoir shall not be less than the following dimensions, namely—

An embankment	25 feet deep	not less than	6 feet wide.
,,	50	,,	12 ,,
,,	75	,,	18 ,,

Intermediate, or lesser, or greater depths of embankment may have proportionately arranged widths.

11. The finished top-bank level of any reservoir shall not be at less than the following elevations, above the edge of the by-wash, or top water line of a full reservoir, namely:—

An embankment	25 feet deep,	not less than	4 feet.
,,	50	,,	5 feet.
,,	75	,,	6 feet.

Intermediate, or lesser, or greater depths of embankment may have proportionately arranged relative top-bank and and by-wash levels.

12. Each impounding reservoir shall have full and free by-wash space not less than 3 feet in length for every hundred acres of gathering ground; such by-wash, where practicable, to be formed in the solid ground.

13. Cast-iron pipes, culverts of timber, or other material liable to decay, shall not be used for outlet discharge, or for overflow works, if required to be buried under or within any reservoir embankment in such manner, and of such dimensions, as to preclude repairs, and endanger the structure by decay. Valves and sluices should be placed within the line of puddle wall.

14. A reservoir embankment shall, at all times, be preserved at its full height, and the relative level of the top bank and by-wash be preserved.

15. All reservoir works and apparatus, such as goits, culverts, tunnels, conduits, bye-washes, cloughs, sluices, valves, and working machinery connected with such cloughs, sluices, and valves, shall be maintained sound and in good working order.

Reservoirs for service distribution should be covered.

Water should not be exposed in open reservoirs and tanks after filtration.

Cast-iron pipes, properly varnished, should be used for street mains. It is not advisable to use mains less in internal diameter than 3 in.

Lead should not be used either in service pipes or in house cisterns. Wrought-iron tubes, with screw joints, may be used for house service. All house taps should have screw joints, and be of the description known as screw down, so as to admit of easy repairs.

In jointing and fixing wrought-iron service pipes care should be taken to insert double screw joints at convenient points, to allow the removal of a length of pipe for alterations and repairs.

Up-bends should be avoided, or a tap should be inserted to allow any accumulation of air to escape.

Wrought-iron service pipes are cheaper, stronger, and more easily fitted than service pipes of lead. Certain sorts of made ground in towns act rapidly and injuriously on both lead and iron pipes—furnace ashes, waste gas and chemical refuse, old building refuse containing lime and other such material. Pipes should not be laid in such material without a lining of sand or puddle, or other special protection.

Earthenware pipes may be used for water conduits, provided the joints are not placed under pressure.

A public supply of water should not be less in volume than 20 gallons daily per head of the population. This, in towns below 20,000 population, will include water for public purposes and for trade requirements.

High pressure and constant service should be secured wherever practicable.

Water at and below six degrees of hardness is "soft" water; above this range water is "hard".

Hardness in water implies one grain of bi-carbonate or sulphate of lime in each gallon of water.

Each degree of hardness destroys 2¼ oz. of soap in each 100 gallons of water used for washing. Soft water is therefore, commercially, of more value than hard water, in proportion to the worth of 5 oz. of soap to each 200 gallons for each degree of hardness. But soft water is also more wholsome, and effects saving in other operations—tea making, and in generating steam power.

LOCAL RAILWAYS.

A very important problem, that of branch railroads connecting small places with each other, and with the main lines, is being resolved in France. The honour of the initiative belongs to the department of the Bas-Rhin, whose conseil-général, in 1858, came to the determination that it was desirable to create a second series of roads uniting the principal places in each commune, and to offer these to companies or local speculators for the formation of railways. There was, however, considerable opposition, one party objecting that the funds of the road trust, as it would be called in England, could not properly be applied to the formation of roads to be converted into railways, and another, that local railroads were the mere dreams of theorists. Last year, however, the project obtained the support of the ministers of state and of agriculture, M. Rouher and M. Behic, who supported the proposals in the conseils-géneraux of the Puy-de-Dôme and of the Bouches-du-Rhône. The prefect of the Bas-Rhin had, in the meantime, pushed forward his scheme, and in 1859 he obtained the sanction of the departmental authorities. He then opened up correspondence with the Great Eastern Railway of France, but the negociations ended in nothing, and it was determined to form local companies for the purpose, and in 1861 a supplementary tax of 26 centimes (about a shilling in the pound), extending from 1861 to 1871, was made for the special purpose, and the work was commenced. On the 25th of September, 1864, the first of these departmental lines, about 47 miles in length, was opened for traffic. The government recognised the importance of the new movement, the ministers of the interior and of commerce determined on framing a special law upon the subject, and a commission issued from the office of the latter minister to collect full information upon the subject.

The example of the Bas-Rhin was soon imitated by its neighbour, the department of the Haut-Rhin, in which a line from Hagueneau to Niederbroun was opened on the 18th, and another from Sainte Marie-aux-Mines to Schelestadt on the 29th of December last. The department of Sarthe has voted the means for carrying out three such local lines. Ain, which is very badly off as regards railway communication, is now engaged on the question; and several other departments have adopted the idea and are now occupied with its realisation. In that of the Seine-Inférieur surveys are being made for a line to connect St. Valery-en-Caux with the Rouen and Havre railway, and which is intended to form part of a complete system which will unite the whole of the small places on that coast with the trunk line in question.

The results, in a financial point of view, can only be guessed at by the short experience of the line in the Bas-Rhin; this road was opened for passengers on the 25th of September, and for heavy traffic, in part, on the 24th October, and completely on the 29th December last, when the weather was very bad, and the conditions consequently disadvantageous. The total receipts, from the 27th September to the 31st December, were equal to £2939, or, on an average, of £320 for little more than $\frac{4}{10}$ of a mile. The profit resulting is given at 2000 francs per kilomètre, or about £130 per English mile. The nature of the traffic is a very important question. The Barr line has fifteen stations, that is to say, one for each commune; this was used by 70,000 persons, who paid a total of 60,293 francs, or, on an average, 86 centimes per passenger. This is tolerably conclusive evidence that the traffic of the line was emiuently local, and independent of the general railway traffic of the country. There is another proof in the fact that the total of arrivals and departures at the station of Strasburg, on the main line, during the same period, was only 47,768, which leaves 22,232 for the purely local circulation, without taking into account those which may have travelled for local purposes between the chief town and intermediate stations on the trunk line.

It is not intended that great speed should be attained on these local lines, and therefore the question of curves and gradients becomes of smaller importance. In the Haute-Marne the minimum radius is fixed at 250 mètres; in the Indre it has been set at 300. The inclines adopted in the Haute-Marne vary from 0·02 to 0·018 per mètre. Lastly, some of the local lines will be worked by horses, while the engines and carriages employed on the others are of a smaller and less costly kind than those used on the main lines. In the Bas-Rhin the expense of the new roads has been 45,000 francs per kilomètre, while it has cost the Great Eastern Company, which has become the *concessionaire* of the line, 60,000 francs per kilomètre to convert the new roads into railroads, and provide machinery and material.

Thus the total cost of these local lines may be taken roughly at an average of 115,000 francs per kilomètre, while the Paris and Orleans cost 368,000 francs, and the Rouen line 404,000 francs per kilomètre. It is not easy to exaggerate the results which may arise from the complete carrying out of this system of rural railways, and any fact connected with it is of importance.

LOW'S PATENT BORING MACHINES, &c.*

By John Downie.

(*With an Engraving.*)

Machine for Tunnelling and Driving Adits.

Figs. 1 and 2, Plate 26, exhibit the machinery employed in driving tunnels. In these the carriage frame is so constructed as to enable the borer to be placed in any part and position, and to bore at any angle, in any direction on the face or sides of the tunnel, and consists of a strong open cast-iron frame A, supporting one or two columns B, according to the number of borers used, and runs upon four wheels fitted with propelling gear C. In order to convey the machine to or from the rock at intervals required for blasting, it is fitted with a double break DD, to press upon the rails, and also with a powerful screw clamp at top, actuated by a worm and worm-wheel E, so that upon the machine being adjusted against the face of the rock for working, the break is screwed upon the wheel, and the clamp jammed against the top of tunnel. Upon the column aforesaid is mounted a jib F, which carries the boring cylinder by the two trunnions. The jib F, can be moved up and down the column on a screw inside, by a worm and worm-nut, actuated by a hand-wheel G; and upon a clutch being put into gear with the screw and worm-nut by lever M, the same handle G will move the column from side to side by turning the screw-shaft, which has a pinion working in a rack in the top and bottom cross slide-bars HH. The jib F, is provided with a double ledged circular rest at bottom I (next the clamps which carry the jib on column). Between the double circular ledge is a worm-wheel cast on the jib, into which a worm, actuated by a handle K, which will cause the jib to turn round. Upon the jib clamps LL, being slackened, it will swing round the column. Thus it will be seen that the boring cylinder has five different movements, viz.—

1. The boring cylinder can transit horizontally or at any angle from the horizontal to vertical position.
2. The jib with cylinder can transit completely round and sideways.
3. The jib with cylinder can swing round the column.
4. The jib with cylinder can be raised up or lowered down the column.
5. The column with jib and cylinder can be moved from side to side.

All the above various movements are provided with powerful breaks, so as to render the whole perfectly steady whilst at work in any direction.

The lower part of the carriage frame is constructed as low as possible, and there is ample room between the columns which will allow a passage low and wide enough to convey the *debris* through, whilst the machine is at work, either by wheeling, carrying, pitching, or otherwise.

* Continued from page 195.

LOW'S PATENT BORING MACHINES.

Fig. 1.

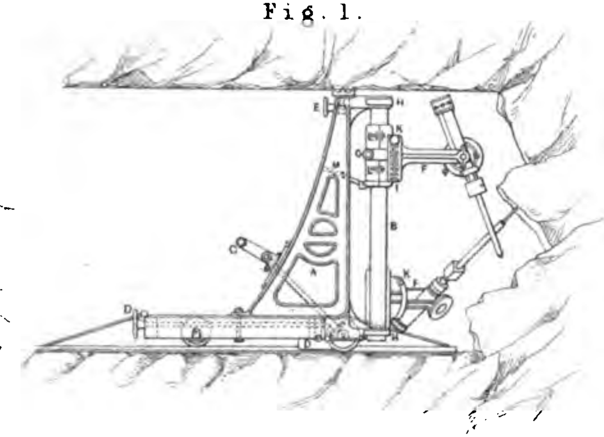


Fig. 2.

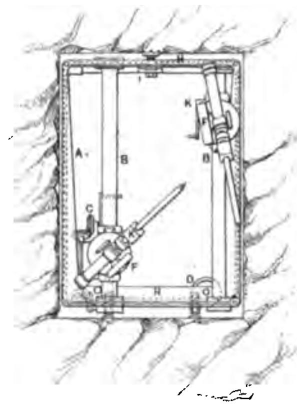


Fig. 3.

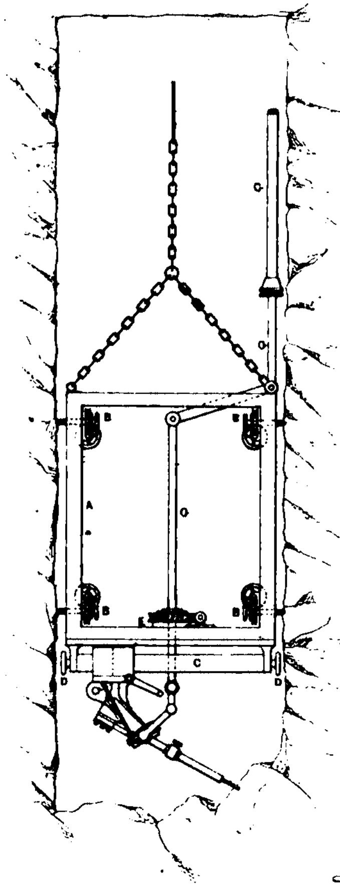


Fig. 4.

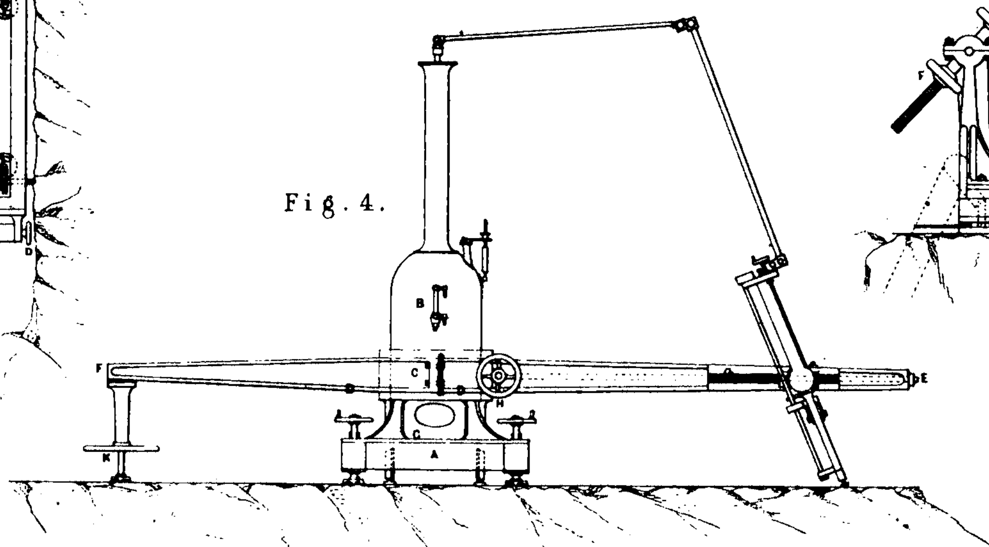
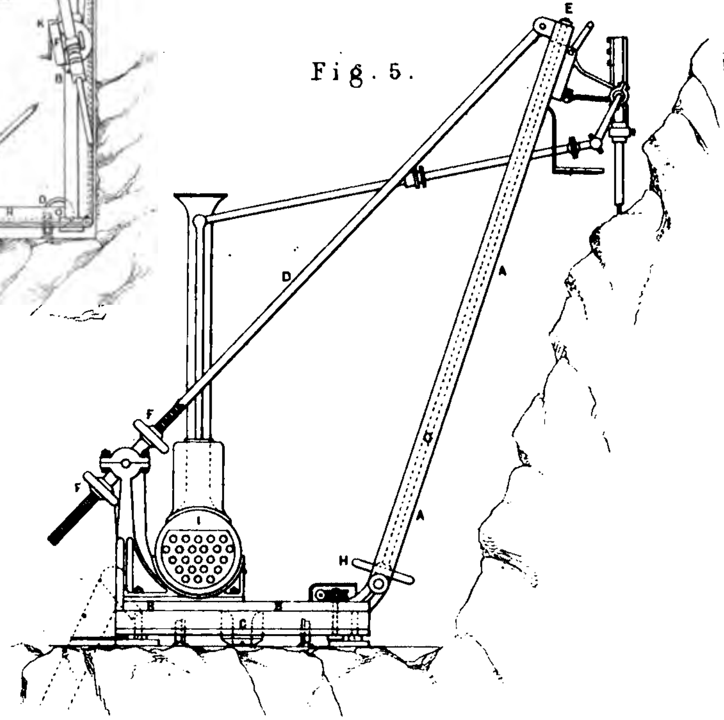


Fig. 5.



J.R. Jobbins

Machine for sinking Perpendicular Shafts (Fig. 3).

The carriage frame or cage A, for carrying the borer, is an open framework hung by a chain, and is furnished with eight screw clamps BBBB, which are clamped against the sides of shafts when lowered to the proper place for operating. The boring cylinder and jib is carried on a horizontal column C, along which it can be moved when necessary by a screw inside by hand-wheels at each end DD. The column C, is affixed to a circular swivel table E, which turns on its centre by a worm-wheel and worm F, so that the tool may be turned round to work in any direction or at any angle required, being provided with four different movements viz.—

1. Boring cylinder and tool can transit in jib end.
2. Boring cylinder and tool with jib may be turned round sideways.
3. Boring cylinder and tool with jib may be moved along the column.
4. The swivel table carrying the whole can be turned round.

The steam or air pipe G, to supply the cylinder, is adapted to the centre of swivel table, so that there is no difficulty in turning it round. The frame and swivel table is made of openwork, so that the *débris* can easily be drawn up through the frame without the necessity of hoisting the frame itself. According as the work proceeds the frame can be lowered by loosening the clamps, lowering to the required position, and then re-clamping.

Machine adapted for working upon surface of Level Quarries, or Top of Cutting and Level Ground (Fig. 4.)

This consists of a carriage A, upon four flanged wheels, carrying a vertical steam-boiler B, in centre, around which is a massive cast-iron circular pivot bracket C, bolted to the carriage frame, and has a circular groove in which a strong ring or table D, carrying two long horizontal jibs E and F, which will swing round the carriage, and is provided with a powerful break to secure it in any desired position. On one of the aforesaid horizontal jibs E, is mounted the boring cylinder, which can be moved along the jib by a double screw G. The double screw is geared into a partial hollow globe, and actuated by the hand-wheel H, in which a ball or globe cast on the boring cylinder fits this, and will allow the boring cylinder with tool to be set at any moderate angle. To operate downwards upon the surface of the ground, a break is provided in the outer hollow globe. To secure the boring cylinder at whatever angle it may be set at, the end of the other horizontal jib F (which is continued on the other side of pivot carriage, opposite the other jib carrying the boring cylinder) is furnished with a lengthened screw K, to clamp against the ground, so that the strain of the working may be communicated through the two jibs on the screw clamp, and tending to lift the carriage, which is half way, so as to steady the whole. This class of boring machine is exceedingly convenient for working upon the top of ledges; as, supposing the horizontal jib carrying the boring cylinder is 15 feet long, the rails can be laid 15 feet from edge of such ledge, and parallel thereto; so that it will be seen that 15 feet of material, and to a certain depth all along one side of the rails can be removed before it is necessary to shift the rails, whilst to remove the rock under the rails, the jib can be turned to operate at the end of the rails, and as the rock is displaced the machine is gradually moved forward, and the rails taken up, to be laid on a new surface lower down.

Machine for Working against the face of Quarries or open Cuttings (Fig. 5.)

The jib with boring cylinder and tool are mounted between two columns or posts A A, which are jointed to a turn-table B, on top of carriage C, so that they can be set at any angle to suit the slope of the cutting, &c. A tension rod D, is attached to the top of the posts at E; the lower end is secured to the carriage turn-table D, by double screw hand-wheels at F F, which, upon being turned either way, will alter the posts A A, to the required angle. The jib with boring cylinder and tool is raised or lowered to the required position by a screw shaft G, actuated by a hand-wheel H, at bottom. The boring cylinder and tool has all the various movements as described in the others. The whole is carried upon a turn-table B, affixed to the top of carriage C, so that it can be set to operate at end of cutting or either side. The steam-boiler I, supplying the working cylinder, is mounted on the carriage, which by its weight will increase its stability when at work, and to further which the carriage is provided with two long ground breaks, K K, under each side of the carriage.

This boring machine is adapted to work slate quarries by adopting ledges 20 feet, one above the other, round the quarry, and along which rails are laid for the carriage to run on.

Low's Machine may also be adapted and arranged for coal cutting although it is more particularly adapted for boring hard rocks or minerals, such as "yellow," "grey," or "peacock" ores, (sulphuret of copper), and the "mundic" (arsenurite or sulphuret of iron), found, for instance, in the mines of Devonshire, Cornwall, Wexford, Portugal, and elsewhere, in nearly all copper mines throughout the world. In using it for obtaining coal on either system, it can be so modified that in driving "adits" or "headings," or working coals "stoop and room," where the roof is dangerous, it will cut and trench three feet deep all round the sides by a traversing motion in addition to the percussive blows; while at the same time a central hole can be bored and widened at the bottom in the usual way, which, on being blasted, will dislocate the whole mass, and if it be objectionable to blast, as in some coal mines, the mass may be dislocated by driving wedges in the trench. In the "long wall" system of "holeing" or "kirving" coal, the machine can be adapted to cut a continuous trench along the bottom of the seam, by which two successive displacements of coal can be effected, each three feet, or six feet altogether, before the rails need be shifted nearer to the face of the "benk" or working, and where there is a good firm roof, this must be a very obvious advantage in many respects. In addition to the above, vertical and angular cutting may also be effected by this machine, and all the movements made self-acting if desired.

Indeed the advantages peculiar to these machines appear so self-evident, that further comment becomes superfluous.

ON METEOROLOGICAL OBSERVATIONS AS MADE IN HOLLAND.

By Dr. C. H. D. Buijs-Ballot.

Professor of Mathematics at Utrecht University, and Director of the Royal Netherlands Meteorological Institute and Observatory at Utrecht.

A Dutch seafaring man named Klein, formerly captain on board a Dutch East Indiaman, published some two years ago a small pamphlet compiled by him from a larger work of mine, the title of which reads in Dutch, 'Eenige regelen van Weersverandering in Nederland,' published by Kemink and Sons, at Utrecht, in 1860.*

My present purpose is briefly to state in how far the system of meteorological observations as introduced in the Netherlands (Holland) since 1860, is superior to the systems introduced and carried out abroad. The Dutch system was approved of by Government after examining scientific and practical men on the subject, and is in full operation.

The rules for foretelling the weather, or some features of the weather, rain, thunder, wind, are of different kinds. In the first class we may place those rules which were laid down in the preceding century, and which are to be found on the scales of nearly every barometer—stormy, wet, fine, &c. These rules, to judge from the actual readings of barometers and thermometers, as to rain and wind that will probably follow, have been accurately tested with the old Dutch observations. So, for the Netherlands, these rules ought to be modified for different localities, the probability of rain, and of such quantity of rain is indicated when the temperature is so much above the average in winter, or so much below it in summer; and when the barometer is so much above or below the average, say five, ten, or twenty millimetres. In the same manner, from several years of observation, it is deduced what is the probability of a storm of such a force when the mercury in the torricellian tube is so much beyond the average of that day of the year.

In all this there is no great difference in the Dutch system with the systems of other countries, save this, that by a long series of observations at Haarlem and Swanenburg since 1759, and at other places, and by comparisons of the last thirteen years at Utrecht, Maastricht, Helder, with Haarlem, &c., the average height of the barometer and thermometer is accurately calculated

* This pamphlet was translated into English by Dr. M. A. Adriani, and may be obtained at 1, Wine-office-court, Fleet-street, or at 149, Strand.

for every day of the year. All those determinations are connected with other long series of observations at Brussels, Prague, Breslau, St. Petersburg, Munich, Rome, Geneva, Toulouse, &c., and so the average height of barometer and thermometer is determined for several places in Europe, in my paper, "Sur la marche annuelle du baromètre et du thermomètre en Neerlande et en divers lieux de l'Europe, publié par l'Academie Royale de Science d'Amsterdam, 1861." (Sulpke, Amsterdam.)

It is obvious, but not generally acknowledged, that no absolute reading of the barometer has any signification, but only the difference (called departure) of an actual reading with the average reading of *that* instrument at the *same* place, at that latitude, longitude and height above the sea on the same day. The departure is the true and accurate measure of the perturbance, and intimately connected, but, as we shall see, not identical, with the force that tries to restore the equilibrium. The single reading of the barometer, on the contrary, is an arbitrary number of no signification at all, unless you substitute an accurate approximation of the average height of the readings. I therefore call the determination of the average or normal height *the* characteristic of the Dutch system, and this base is adopted in the Dutch meteorological Annuaires, which have appeared regularly since 1852, and wherein for every day of the year a tabular view is given, representing the departure of temperature and atmospheric pressure for the whole of Europe.

In the second place there are other rules. The rules of the first class, the oldest and roughest, are thought insufficient. So it is really, they have some value, and as empirical rules they may be used. But further investigations have proved that the weather of a certain day and place, is not the weather, viz., the temperature, the wind, the moisture, &c. excited by the sun that day and at that same place, but the resultant of the weather brought about by the currents of air from the surrounding places, and, much to the distress of meteorologists, from the higher strata of the atmosphere. It is therefore that the observations of Mr. Glaisher, whose perseverance and skill are beyond all praise, are valuable to meteorological science. Therefore a record, giving at small expense the state of the higher strata of the atmosphere would be invaluable, for when the state of the weather is recognised not to depend chiefly upon the action at the place itself, but to be influenced by that state in surrounding localities, it is evident that communications should be obtained from those districts. The Netherlands have so little surface that I dare not assign a marked difference to any locality indicated there. The rules of this class are to me only these: that when at Bayonne, at Cherbourg, and at Brest, there is a heavy sea and much wind, and when the barometer gives indications of coming storms, I give warning to all the seaports of my country.

I have to explain a third class of rules more especially characteristic of the Dutch system of foretelling the weather. That system does not overlook the rules of the former classes, but I think that to observe them is a step more in advance, when I pay full attention not only to the departure at a certain place, but to the difference of simultaneous departures at different places. For instance, there may be a departure of 1 English inch at Paris; then it is a dangerous case: it is probable, from the rule of the first class, that there will come a strong wind or storm; further, from the rule of the second class, it may be ascertained with some probability if a strong wind commences to blow, that it will proceed to Belgium, the day afterwards to Holland, then to Hamburg, or at some more easterly situated places. When however the barometer is 0·7, 0·8 or 0·9 inch too low, not only in France, but in Germany, England, Holland, and throughout Europe at the same time, then it may be entirely quiet for some days. It is evident from itself, for when all over Europe the pressure is 20 millimetres less, why should these originate a strong wind in Austria? The wind will originate at the circumference where the negative departure is not so great, and where the places with positive departures are near. Then we may infer that the wind will originate at those regions where over a small country the difference of simultaneous departures is great, or, you may say, where the inclination of the atmosphere is sensible; where the positive departure is greater, the height of the atmosphere, or rather the average condensation (elasticity) of the air is greater, and therefrom the air is pushed towards the places with less positive departures, or greater negative departures. Now this theoretical rule is tested by the very accurately known simultaneous departures in the Netherlands at Helder (H), Groningen (G), more northern places, and Maastricht (M), and Flushing (V), the two southern places; and it is found that if the more southwardly situated places indicated by (M) and (V) are above the more northwardly situated ones (H) and (G), the wind will have the letter W in its name, and when the departures are more positive at Helder and Groningen the wind will have an E in its name. More accurately, it may be stated thus: according to the rule found for storms in Ireland by the Rev. Dr. Lloyd, in Dublin, that the deepest depression of the barometer is at the left hand of the storm, where it is raging, according, therefore, with the theories of hurricanes of Mr. Redfield, and other investigators in the same field, the wind which will blow shall be in such a direction that it will have at nearly right angles of its left the most negative departure, viz., the place where the pressure is least.

To the paper of M. Klein I have added a statistical table, to show in how many instances in a hundred this rule for the *direction* holds true; and as to the strength of the wind I have found that it matters not much for our country if the northern places have much greater pressure than the southern places, since east winds are not strong in Holland nor dangerous for the shipping on our coasts; but that there will be a strong wind, a gale, or a storm, if the difference of simultaneous departures at (M) or (V) above (H) or (G) is 4 millimetres or more. At the foot of the copies in writing of the telegraphical communications there is written a line containing, firstly, the name of the place where the departure is most positive, say M, at the end the name of the place where the pressure was lowest, and between the difference of the departures, say 4·5: viz., M 4·5 below H means danger for a south-west and west strong wind; V 4·5 below G means danger for a westerly or north-westerly storm, and so on.

In comparison with the warnings of the late Admiral Fitzroy, taken from his eleventh meteorological paper, I have added a table showing what warnings were given in the ports of the Netherlands. I must, however, acknowledge that these warnings are not so publicly or officially given in the Netherlands as in England, but at several places, such as Flushing, Amsterdam, and Helder the shipmasters may obtain the simultaneous departure of the barometer in the different post-towns early in the morning, and they can see what conclusion is drawn therefrom.

COMMUNICATION BETWEEN DIFFERENT PARTS OF A RAILWAY TRAIN.

THE subject of intercommunication between the different parts of railway passenger trains while in motion, is one which has occupied the attention of the public for a long period, and has called into exercise much ingenuity to devise an efficient and economical means for its accomplishment. Some months since Captain Tyler, R.E., was requested to report to the Board of Trade the results of a very careful and complete investigation which he had made into the subject, and which has only just been published. Its interest and importance induce us to lay it before our readers *in extenso*. Captain Tyler states:—

This question, which has received much attention from time to time, both in this country and on the Continent, has of late undergone considerable change. In former years numerous accidents occurred in which carriages were dragged along, sometimes for miles, in a disabled condition, or on fire, unknown to the engine-driver; and it has been principally in consequence of such accidents that, first the Commissioners of Railways, and afterwards their lordships, have addressed circular letters from time to time to the different railway companies.

The subject had attracted much attention previous to 1847; and in October of that year a circular was issued by the then Commissioners of Railways, Lord Granville, Sir Edward Ryan, and Mr. Strutt, after communication with the Great Western and London and North-Western Railway Companies, describing the methods proposed to be adopted by those two companies:—the Great Western, of employing a travelling porter to keep watch from a box at the back of the tender; and the London and North-Western, of employing a guard to look out from a van next behind the tender for any signal from the passengers or hind guard, or for any symptoms of accident in the train. The London and North-Western Company also proposed that the under guard riding next to the tender should have the power of sounding a whistle on the engine. A forcible illustration of the necessity for such precautions presented itself in October of that year in the case of Lady Zetland, whose carriage was set on fire on the Midland Railway by a spark from the engine.

The Commissioners issued a second circular in October 1851, pointing out how desirable it was that "the power of travelling along trains whilst in motion should be given to the guards and servants of the company," and observing "that the benefit derived from that measure may be materially augmented by the more general adoption of seats for the guards, from which they may look along their respective trains, so that they may readily perceive whenever anything in their trains may require their attention."

The practice at that time in Belgium was the same that has since been followed in that country—of employing the guards to travel along the footboards outside of the carriages; and several of the English companies having expressed their willingness to adopt this arrangement, the consent of the Postmaster General was obtained for the addition of steps to the Post Office vehicles, with a view to its being generally carried out. After further communication between the Board of Trade, the railway companies, and the Clearing-house, a sub-committee was appointed at the Clearing-house by a minute of the general managers, dated 4th February, 1852, to consider the proposal of the Board of Trade to use the footboards of the carriages as a means of communication on the outside of trains; and the sub-committee drew up a list of queries, and circulated them among all the railway companies of the United Kingdom. They received replies from thirty-five companies, from which it appeared that there were twenty-three companies on whose lines either bridges, tunnels, or other permanent structures rendered it dangerous to pass along the side of a train in motion; there were sixteen companies whose station platforms would have required alteration if the footboards of the carriages had been lengthened; and all these companies were in the habit of running cattle-trucks or goods-trucks to a greater or less extent with their passenger trains. All but two stated that no accident had occurred which might have been thus prevented, and that they considered the power of passing along the footboards would lead to rash exposure on the part of the public. All but five thought that, if passengers were able to move from a lower to a higher class of carriage, they would be likely to take advantage of this means of defrauding the companies. All but one thought the system would afford facilities for robbery and assault upon passengers, and especially on females travelling alone. Four companies had employed the system for general purposes, and two especially for the collection of tickets. But one had discontinued it from apprehension of danger, and another after an accident; and a third did not consider that it had been attended with benefit or the reverse. All but three thought that the disadvantages of its adoption would preponderate.

The committee came finally to the conclusion:—"That there are several railways the dimensions of whose permanent structures would prevent the plan from being generally adopted, without which it would be inoperative; that the expense of the alteration (which they estimated at £165,855) would be out of all proportion to the benefits that would be derived from it; that it would expose the public to great danger and to robbery, and the companies to fraud; and that therefore it is not desirable to adopt it."

I may here add, by way of parenthesis, that the difficulties of such communications have increased since the year 1852, in consequence of the greater width of the carriages on different lines. And it must not be forgotten that the apprehensions above expressed were actually realised, by the murder of M. Poinsot on a French railway, in December 1860; the assassin having apparently obtained access to, and escaped from, the compartment in which M. Poinsot travelled by means of the footboards.

The subject was allowed to drop after the receipt of the above report from the Clearing-house, until a serious accident on the Buckinghamshire Railway caused it again to be brought forward. Captain (now Colonel Simmons) of the Royal Engineers, then drew up a memorandum (on the 12th February, 1853) on the measures which had been adopted in France and Belgium, and made suggestions with reference to the British railways. The French law provided as follows:—"Les conducteurs gardes freins seront mis en communication avec le mecanicien, pour donner en cas d'accident le signal d'alarme, par tel moyen qui sera autorise par le ministre des travaux publics sur la proposition de la compagnie."

And the law was so far put in force that a guard in the leading carriage of each train was provided with a cord connected with a bell on the tender; but no greater advantage was obtained by this method than by the system previously referred to as having been adopted on the Great Western Railway of England, of placing a travelling porter to keep a look out from a box on the back of the tender; and numerous experiments which were made in France with a view to the more perfect system of providing a communication throughout the whole length of a train were not productive of any useful result.

Colonel Simmons concluded his memorandum by recommending:—"First, that a communication should be established between a guard to be stationed in the front of a train and the driver, as in France; second, that this guard should be placed in a box or van, so that his most convenient and natural position, when the train is in motion, should be with his face to the rear, and looking along the train; and third, that a guard should always be placed on the last carriage of the train." And he contemplated the guards exchanging signals by flags and lamps, and making use of the footboards when necessary.

In consequence of further agitation, the Clearing-house committee of general managers met again in the latter part of 1852, and re-appointed a sub-committee, "with the view to ascertain whether a plan for establishing such a means of communication can be devised which would not create greater danger than it is designed to guard against." They addressed letters to all the British and to the principal Continental railway companies; they investigated the merits of the plan which had thus been proposed to them by their lordships; they inspected and considered the models, drawings, and descriptions of numerous correspondents and inventors; and they finally drew up an elaborate report in March 1853. They found that the only arrangements which were in actual use were, (1) voltaic communication, on the Orleans Railway, which had not answered well; (2) a mirror on the Montpellier à Cette Railway, placed in front of the guard, in which the train was reflected, which was admitted to have many defects; (3) a rope attached to a bell on the tender, or to the steam whistle, "carried along the tops of the carriages, supported on brackets, and placed within reach of the guards and brakesmen," as used on the Dutch, and on the Prussian, Hanoverian, and other German railways. With regard to the question of giving the passengers the power of communicating with the guard, they reported as follows:—"Without overlooking the possibility of such an arrangement being occasionally of service, the committee have been unable to persuade themselves that it would not lead to greater disasters than it could, on any view of the matter, prevent. Unless the guards and engine drivers had orders to stop the train whenever a passenger made a signal, the privilege would be useless to the latter. It, however, requires little acquaintance with railway travelling to be convinced that its dangers would be greatly increased if the train were to be stopped whenever and wherever a passenger under the influence of fear or levity chose to make a signal. The committee is not, therefore, prepared, in the first instance, to recommend any arrangement or regulation which would put it in the power of the timid or reckless to control the discretion of the guard or engine-driver, and to put the safety of the whole train in peril." And they added in another place—"Should it, however, appear that the advantage of providing passengers with such means of communication countervails its dangers, the committee see no mechanical difficulty in the way. But it is of opinion that no such concession should be made until the legislature has specially guarded against the abuse of the privilege by making it penal."

After referring to the practice on a German (the Cologne and Minden) railway, on which, according to Herr Minckwir, "three conductors, who during the journey control the time tables and, standing on the side of the carriages, watch over the safety of the passengers, and also three brakesmen, who grease the breaks and axletrees;" and on which "the passenger carriages are so arranged that the officers can pass round them when in motion:" and to the American system, "where the railway companies make little distinction as regards passengers, the carriages being so constructed and arranged internally that both the passengers and conductors can move from one carriage to another by means of a passage running through the middle of the entire train:" the committee proceed to state—"As regards the first of these modes of enabling the guards to move along the train while in motion, this committee proved in the report on the subject (already referred to) which the Clearing-house committee forwarded last year to the Board of Trade, and to which it now begs to refer, that though the plan of lengthening the footboards of the carriages for this purpose seemed simple and suitable, there were difficulties in the way of its adoption on British railways which are insuperable. And as regards the American arrangement, it is obvious that it is so opposed to the social habits of the English, and would interfere so much with the privacy and comfort which they now enjoy, that these considerations, apart from others nearly as important, would forbid its adoption in this country.

The committee considered that the "electric fluid is too subtile, and the apparatus used for evolving and conducting it too delicate, for the rough usage and the disturbing causes to which they would be exposed when trains are in motion." And they proceeded to state their opinion that a cord or line of hemp, copper wire, or gutta percha, as might be found best in practice, employed for connecting a van at the tail of the train with a bell on the tender, under detailed arrangements which they described, would be found best to fulfil the various conditions of the case. They strongly recommended the companies, parties to the clearing system, to give effect to this plan without delay; and they appointed a committee to assist the associated companies in ensuring uniformity and efficiency in the application of the principles which they laid down.

The members of the select committee of the House of Commons on Railway and Canal Bills of 1853, who had the above Report before them, reported to the House the following resolution: "That provision should be made for enforcing the means of constant communication between all the servants to whom the safety of the passengers in any train is entrusted.

On the 22nd July, 1854, after another accident, their lordships addressed a letter to ten of the principal railway companies, calling attention to that resolution; and on the 5th August in the same year a letter to eighty-seven companies, with reference to that resolution and the Clearing-house Report, concluding as follows: "My lords are desirous of recalling the attention of the directors of the several railway companies to this important subject, in the hope that such measures may be adopted as are calculated to bring this improvement into general use in the most convenient manner; and they direct me to point out how serious a responsibility will be incurred by them, should any accident happen in consequence of their neglect to establish this mode of affording increased security."

The replies of the railway companies to these circulars were, in some cases, a simple acknowledgment; in others to the effect that the directors were making inquiries or taking steps to secure the object in view; in others, that they were prepared to adopt whatever might be adopted on the lines of neighbouring companies; in others, that communication was afforded by the footboards of the carriages; in others, that the bell and rope system recommended by the Clearing-house committee had been tried and found useless; and in others, that it had been brought into use. The Great Western Company still retain their system of a travelling porter on the back of the tender. The London and North-Western Company had ordered the adoption of Professor Glückman's invention, which provided a voltaic communication between the guard and the engine-driver. The London and North-Western Company expended, indeed, a considerable sum of money at that time on apparatus for working the Glückman method, and only abandoned it because they found by experience that it was not effective, from failure in the mode of coupling in very long trains.

On the 30th December, 1857, their lordships again addressed a circular letter to the railway companies, calling attention to two recent accidents by fire; the one on the Great Western Railway (to a train on which there was no travelling porter), and the other on the Lancaster and Carlisle Railway; stating that twenty-six accidents had occurred during the previous four years, "in which either the accidents themselves, or some of the ulterior consequences of the accidents, would probably have been avoided had such a means of communication existed;" referring to the Clearing-house Report of 1853, and requesting to know how far the wishes of the legislature, as expressed in the recommendations of the select committee of 1853, had been carried into effect. The replies to this circular were not materially different from those referred to previously, which were made to the circular of 1854; rope and wire communications having been adopted by some companies; the sudden application of the guards' break having been depended upon by others; the footboards having been considered available on some lines; and no communication having been found necessary, or possible, on others. The select committee of the House of Commons on railway accidents in 1858, after hearing a great deal of evidence from all quarters on the subject of communication, both between passengers and guards, and between guards and engine-drivers, recommended as follows:—"That your committee is also of opinion that it should be imperative on every railway company to establish means of communication between guards and engine-drivers." On the 27th September, 1858, in forwarding a circular letter to the railway companies on the subject of extra break power on passenger trains, their lordships drew attention to the advisability of some other means of communication being provided between the engine-driver and the guards than by the steam-whistle, and concluded as follows:—"My lords regret that the railway companies have as yet made so little progress in adopting a means of communication between the engine-drivers and guards of trains, by means of a cord or otherwise, which shall be certain of attracting the immediate attention of either the guard or driver, and not be liable to be misunderstood; and my lords trust they will no longer delay to provide an efficient means of communication as well as a sufficiency of break power for stopping the trains." And on the 30th July, 1864, their lordships addressed their last circular letter to the railway companies, calling attention to "recent occurrences of a criminal nature, as well as to the complaints frequently urged on their attention of the danger existing or apprehended (in case of accidents) from the want of means of communication between the different portions of a railway train while in motion." Nothing new was elicited in the replies to this circular.

I have already quoted the French law on this subject, and stated the measures which were taken, up to 1853, towards carrying it into effect; and I may now refer to the report in 1863 of the distinguished French commission, which was nominated on the 5th November, 1861. The commissioners show that the feeling amongst the French railway companies is much the same as that which has been expressed by the English railway companies, in the following sentence:—

"Rélativement à l'établissement d'une communication entre les agents du train et les voyageurs, les compagnies ont unainement déclarées que cette communication était inadmissable parce qu'elle occasionnerait plus de dangers qu'elle ne rendrait de services."

The commissioners refer to the report of the French commission of inquiry in 1857, which was against any communication between passengers and guards on the score of economy as well as of practicability; and to the report of the three ingenieurs-en-chief des ponts et chaussees who were appointed specially (after the death of M. Poinsot) to consider the question of the security of passengers in trains in motion. This last commission, who reported on the 12th of April, 1861—

"Ecarta tout d'abord l'idée d'une communication entre les voyageurs et les agents du train. Elle se borna a demander qui les compagnies fussent invitées:—1. A pratiquer dans le délai de six mois dans les compartiments de 1 et 2 classe une ou deux ouverturès fermées par une glace transparente et placées au dessus des filets à voyages. 2. A organiser dans le même délai sur toutes les voitures composant les trains de voyageurs un système de marchepieds et de mains courantes horisontales qui permette, soit aux agents du train, soit à des contrôleurs speciaux, de parcourir toute la longeur du convoi du côté des accotements du chemin. 3. A presenter au ministre les ordres de service arrêtés par elles pour ce contrôle de route en exécution des prescriptions ci dessus."

And the commission, which reported in 1863, stated their own conclusions as follows:—

"Que toutes les fois que la composition des trains ne s'y opposera pas, la communication entre les gardes freins et le mécanicien devra être rendue obligatoire; qu'il n'y a pas lieu de faire de même, en ce qui touche la communication entre les voyageurs et les agents du train."

Such is briefly the history of this question of communication in railway trains. The result is, that the bell-and-rope system has, within the last few years, been extensively employed for enabling the guards to signal to the engine-drivers, and has been generally successful, though it has sometimes been found to fail, from the jamming of the rope, both in this country and on the Continent, in very long trains. Serious accidents to trains of the description referred to have of late been on the decrease, partly in consequence of its having been adopted, and partly in consequence of the improvements that have been made in the permanent way and rolling stock. But this system is comparatively of little use in the cases to which attention is now more particularly directed—of outrage in railway carriages. And since the murder of Mr. Briggs (which no means of communication could have prevented) other cases have occurred, showing the want of further facilities, which have excited the public feeling to a degree that can best be appreciated by those who travel most. There has been, indeed, a panic amongst railway passengers. Ladies, unable, of course, to discriminate at the moment between those whom they should avoid and those who would be their best protectors, shun all alike; and gentlemen passengers, as well as railway officers of all classes, constantly refuse to travel singly with a stranger of the weaker sex, under the belief that it is only common prudence to avoid in this manner all risk of being accused for purposes of extortion, of insult, or assault.

The latest phase of the question in this country has, therefore, reference more to protection from outrage than to precaution against accident; and there can be no doubt of the desirability of affording, if possible, at reasonable cost, and in a mode not likely to be abused, to every passenger in a train, some facility of attracting attention to the compartment in which he (or she) is travelling in case of urgent need. An increased desire, as well as undoubtedly an increased necessity, for such a facility, is caused by the improvement which has been wisely introduced upon the different lines, of longer runs and fewer stoppages, wherever the nature and amount of the traffic has been found to justify it, as the best and safest mode of accelerating the speed of the trains. Thus, trains run now daily, without stopping, on the—

	Miles.	Hrs.	Mins.
South-Eastern Railway, from London to Dover, for ...	88	1	55
London and North-Western, Chester to Holyhead, for	84	2	7
" " " London to Rugby, for ...	82½	1	50
Great-Western, London to Swindon	77¼	1	30
Great-Northern, London to Peterborough	76¼	1	37
London and South-Western, London to Basingstoke ...	48	1	10

and for distances not much shorter on many other lines, or on other portions of the same lines, which I need not enumerate.

The facility of communication would tend at once to restore confidence to the travelling public, and to have a powerful deterrent influence on the evil-disposed; and the less the apparatus was employed, the more would the object of providing it have been attained. In America, a cord under the roof, and free circulation through the carriages, do all that is required; but the great difficulty to be contended with in this country, in any attempt to combine efficiency with reasonable cost, consists in the necessity which appears to exist, not only for providing handles or instruments on the inside of each compartment of every carriage for communicating with the servants of the company, but also for connecting those instruments with outside signals to direct them to that part of the train from which an alarm has been given, and in the event of a false alarm to ensure the discovery of the offender.

And there is further the difficulty of enabling any servant of the company to visit a compartment from which a signal may have been given while the train is in motion, to ascertain the cause of alarm. I have already adverted, and shall hereafter say more in regard to the danger of permitting communication along the footboards of the carriages which are in use on many lines, for want of space on either side of the train. It would not be advisable in many cases, or as a rule, to stop a train at once on an alarm being given; and I cannot consider that the difficulty would be satisfactorily met, even if the roofs of the carriages were on the same level, by constructing a tramway and covered passage, as has been proposed, along the tops of the carriages, through which the guard or a travelling porter should push himself backwards and forwards in a truck in a reclining posture. The only practical remedy that remains is to provide that when a signal from a passenger has been given, the servants of the company should, if they have no means of ascertaining the cause, and are unable to discover any good reason for immediate stoppage, proceed forward to the next fixed signals, and come to a stand under their protection. This would seldom lead to a serious delay in pulling up, and it would materially decrease the risk of an unusual stoppage, which is not slight in some localities, and under the arrangements on which many lines are worked. Of course, in case of fire, or of a carriage being disabled, the train must be stopped at all hazards; but it will in other cases be wise to leave it to the discretion of the servants of the company to stop their trains as speedily as they can do so with safety, under the circumstances of each particular case.

I annex an abstract of the proposals which have been made to their lordships in official communications, and I shall next proceed to describe the different classes of methods which have been proposed here and abroad for providing communication in trains, and to make some remarks upon them:—

1. Bells, gongs, whistles, detonating, and other *sound* signals on separate carriages, connected with outside indicators of different descriptions, to attract attention to the part of the train from which the sound proceeds. Such signals rendering each carriage independent, and requiring no extra coupling between the carriages, would be admirable if they could be made efficient. But unfortunately, there is no certainty of their being heard, even from front to rear in a long train; and they are frequently inaudible under the most favourable conditions, when a train is travelling at high speed, towards the front. The rattle of a train, in passing particularly through cuttings, or tunnels, or bridges, is so great as sometimes to render the steam whistle of the engine inaudible to the guard in his van.

On this point the Clearing-house Committee of 1853 observe:—"The remarks made in a former part of this report, when treating of air whistles, prove that signals depending on sound, if made at a distance from the engine driver, are as little to be relied on as those depending on sight. Several members of the committee have at various times conducted experiments having sound for their basis; and the result has invaribly been that no noise, however loud, shrill, or continued, whether the sound was produced by compressed air, trumpets, or gunpowder, could be heard, even when the train was short, when there was a head wind, or when the speed of the train was considerable."

My own view on this subject was confirmed by some experiments which the London and South Western Company and Mr. Edmund Tattersall were good enough to allow me to make recently with bell signals fitted up on carriages on the London and South-Western Railway.

Explosive signals, also, would be liable to fail, after lying ready perhaps for years, when they were required for use.

2. Separate *sight* signals on each carriage, independently of sound. Signals of this class also have the advantage of requiring no extra coupling between the carriages, but it would be necessary that a servant of the company should be constantly and specially on the look out for them, because the guards have luggage, parcels, papers, to sort and attend to on their journeys. It is further difficult to keep men constantly on the alert in looking out for what is very seldom seen; and these signals would be invisible in thick fog, or in the smoke and steam of a tunnel. The French Commissioners of 1861 remark, pithily, with regard to the above two classes of signals:—"Les Nos. 2, 3, 14, 24, consistent des appareils visuels ou sonores placés sur les voitures des voyageurs. Nous demontrons que leurs signaux visuels ne seraient point vus que leurs signaux sonores ne seraient point entendus."

3. *Mirrors* for the use of the engine-driver or guard, or both, or, as has been proposed, so arranged throughout a train as to give the guard or guards the opportunity of constantly overlooking the interior of every carriage. These again, besides requiring to be constantly cleaned on the journey, would frequently be useless in tunnels and fogs; and it would probably be disagreeable to many passengers of both sexes to be liable to be watched by persons whom they could not see, even if the system of supervision proposed could be rendered suitable for adoption in practice. Mirrors on the engine, or the van, must also, to be of any use, be extended to a more or less inconvenient distance beyond the sides of the train; and extra illumination would be necessary at night. Neither the engine-driver nor the fireman, nor the guard, could be expected to be constantly looking into them

4. *Apparatus* worked by the *revolving axles* of the tender or break vans, such as air-pumps or magnetic arrangements, are open to the objection that they require to be adjusted to extreme variations of speed, and would be useless when the wheels were skidded by the breaks, in slackening speed or in descending steep inclines. It is further desirable that the machinery of communication should be as far as possible independent in its action of the machinery in the train.

5. Tubes throughout the train for the conveyance of sound by a whistle or otherwise, would require some better means than has yet been devised for connecting the action, which leads to the emission of sound, with that of an outside indicator. The

couplings might be made without difficulty; but it is a question that can only be decided by experiment, how far the sound would be heard throughout the length of a long train in motion. On this subject, the French commission remark:—"Les Nos. 17, 26, 28 et 29, croient à l'efficacite de tuyaux accoustiques communiquant sur toute la longeur du train. Il est facile de demontrer que ce système de communication serait au contraire entièrement inefficace."

Tubes for the conveyance of balls, as has also been proposed, by a current of air generated by an air-pump on the axle of the break-van, are open to the objection already referred to under No. 4, and would necessitate the keeping constantly in order of an air-pump on every break-van. This idea has been worked out in a model, the intention being that the passengers should transmit balls to the guard in the normal state of the current, and the guard should have the power of reversing the current to forward balls to the engine-driver.

(To be continued.)

THE ERITH EXPLOSION AND THE REPAIR OF THE THAMES EMBANKMENT.

The following account of the repair of the breach in the River Wall, at Erith, caused by the explosion at the powder magazines in October, 1864, is from a paper by Mr. Lewis Moore, read before the Society of Engineers.* It should be stated that Mr. Moore resided in the locality, and undertook the direction of the work of reparation.

The first step to repair the wall was to set to work the men who were fortunately present, in number about forty; these were set to puddle the rents and deep fissures in the hole caused by the exploded barge, and which were below low-water level, but were temporarily protected by the fragments upheaved around the edge of the hole; had not this been done before the water came into the hole it could never have been got at again, and the whole superstructure, however solid, must have been undermined and washed away. It may be readily inferred that the bases of operations were of the worst possible description, being lumps of earth and clay separated by large fissures several feet in length, and extending under the intended dam. The next thing was to send for assistance from the nearest point; fortunately this was obtainable at the Crossness works, about a mile off, and at the garrison at Woolwich, about four miles distant from the spot. At about ten minutes before nine o'clock the call was promptly responded to by the arrival from the Crossness works of about 350 navvies, with their picks, barrows, &c., who came none too soon to complete the puddling of this treacherous foundation before it was covered by the tide. Between ten and eleven o'clock, 1,500 military arrived, fully equipped with some appropriate implements, and they devoted themselves entirely to the backing up with immense quantities of earth the works which the navvies were puddling in front, thus making it sufficiently substantial—consistent with speed and means at hand—to contend with the now rapidly rising tide. In this, as is well known, by a manful struggle, they only just succeeded—racing as it were inch by inch with the rising waters.

The first and greatest difficulty that presented itself was the portion blown out by the barge in front of the river bank, and below low-water, inasmuch as the soil was very much broken up and disintegrated over a large area, and the time during which puddling could be done was exceedingly limited. An erroneous impression prevailed among some persons present, that it would be necessary to dig out this portion to a good bottom, in the usual manner of commencing the construction of a river wall, and the author had much difficulty in persuading them that immediate puddling of the fissures and broken ground below low-water mark was the only hope of succeeding, inasmuch as the cutting a grip would have occupied all the precious time to be employed in filling up. This puddling was most important in order to prevent percolation, the danger most necessary to be averted. When the navvies arrived from Crossness, they were immediately set to continue this important part of the work, and also the filling of the actual gap; it required some little time to arrange the number of men to advantage, but being accompanied by able superintendents, they were soon allotted to their separate works of digging clay,—wheeling it to the spot,—and carrying water for the punning, where the clay was well worked with iron punners.

While the puddling, &c., was being vigorously carried on by this large force of men, the military arrived, commanded by General Warde and Colonel Hawkins, R.E. The difficulty of immediately rendering available, without confusion, the labour of all these men in so small a compass, and on the spur of the moment, may readily be imagined. With the greatest promptness Colonel Hawkins adopted the suggestions offered him by the author, as to the method of proceeding. Several barrow roads were laid leading to the gap, numbers were employed in digging and loosening earth, filling and wheeling. The number of implements available for the use of the soldiers was, of course, limited; but, nothing daunted, they were formed into lines between the barrow roads, and passed from hand to hand towards the gap the lumps of earth and clay dug up by those at the back, the whole of the clay and earth for that purpose having to be brought from a distance of 60 or 70 yards by the barrow roads and by hand, the soldiers passing lumps from one to another from this distance, which, when deposited in place, were immediately punned down perfectly solid. Having to deal with some 20 feet head of water, it was necessary to extend the width of the dam at the base, which absorbed an incredible amount of earth, the width of the breach being 130 feet. When the tide had reached and filled the front hole, it was found that the level of the water was within 2 feet or 3 feet of the top of the progressing work. The tide rising very rapidly, fears were entertained that sufficient soil could not be obtained to enable the work to keep ahead of the tide. At this juncture, the military produced a quantity of bags used for making sand-bag batteries, a number of men were set to fill them with soil at the back of the work; these bags were at first being thrown in indiscriminately, when the author directed that they should be laid at the back of the puddled face in the form of an arch on plan, to receive the horizontal pressure of the water. These bags were laid in courses, and punned so as to come in perfect contact. By this means the bank could be raised of sufficient strength with about one-half the material, and the disposition of the men was so arranged as not to interfere with the other parts of the work. In this way about 3000 bags were used, and it was satisfactory to find they answered the purpose admirably, but even with this assistance the tide was following the work very closely.

An alarm was now raised that the water was coming in, and it became apparent that there was considerable percolation under the dam—probably through the broken ground upon which so much labour had been bestowed in puddling—and making its appearance many yards at the back of the work, it was difficult to arrive at the treacherous point. This was most disheartening by the knowledge that a small stream would soon increase in newly-made earthwork, and undermine the whole. The exertions were redoubled; but it is feared that these would have proved of no avail but for the timely settlement of the structure, and consequent compression of the substrata. By this providential circumstance the leak was staunched, so that the settlement, apparently a source of great apprehension, proved really a matter for congratulation. Sole attention was now turned to raising the bank, and protecting the face from the wash caused by passing steamers. Timber breakwaters were hastily constructed and floated in front of the work, and this in a great measure protected it from being undermined. By half-past one the tide was at its highest, and the bank was but a few inches above it; the structure successfully withstood the pressure of the water, but it was evident to all that the backing up must be continued before the danger was past, and the men, therefore, worked on until the tide had far receded. A large staff of men continued the operations throughout the night of Saturday.

On Sunday morning the bank was found to have settled some four feet, and, in consequence of high wind from the east and a heavy sea running, threatening to undermine the works, the author telegraphed to General Warde, for 500 sappers and miners, who arrived in time to reinstate the dam. The work of restoring the wall to its original condition, was continued through the month of October, and it is now as secure as any other portion of the embankment.

Breaches of the river walls reclaiming the marshes from the river Thames have been frequent in times gone by. These have not arisen from causes similar to the one under consideration,

* See Transactions, Society of Engineers. London: Spon. 1865.

but from high tides, defective sluices, and even rat-holes. In 1527, the river made an irruption at Plumstead and Erith, and so much land was submerged that it was not all regained until 1590, a matter of sixty-three years. This breach occurred within half a mile of the present one, and there are now existing traces of the existing embankments by which it was reclaimed piecemeal. In the time of Henry the Eighth, the marshes of Plumstead and Lesnes, now the Woolwich practising ground, were submerged by the water coming in from the Erith breach. But the most recent, as well as the most important, was the Dagenham breach, which occurred in 1707, at a point exactly opposite the southern outfall works of the London sewerage. Continued attempts to stop this breach were made for eight years, but without success, when Captain Perry undertook to reclaim it. At this time the breach is stated to have been on one occasion 50 feet below low-water, or 70 feet below high-water, caused by the ingress and egress of the flood and ebb tides. Captain Perry, it is stated, employed 300 men for five years before he succeeded in stopping this breach, making thirteen years in all, during which time an immense quantity of the marshes were washed into the river, greatly obstructing the navigation of that important highway. The means he adopted were, firstly, forming sluices in the river wall to reduce the scour, by allowing freer access to the water, and after so doing he drove dove-tailed or grooved piles from either side of the breach, protecting them as he went on with clay. The increased scour caused by this impediment threatened to deepen the channel so as to be beyond the reach of piles; and if the depth above stated was correct it would have been impossible to have succeeded by this method, so that the inference is that he chose a shallower portion of the breach; certain it is that he did succeed, although at a ruinous cost.

The Dagenham breach began with the failure of a sluice which had been allowed to get out of repair, and quickly extended from a gap of 14 feet, and ultimately led to the obliteration of a thousand acres of land. But that was not all: about 120 acres were actually washed away into the bed of the river by the flow of sullage, and the soil so washed formed a bank about a mile in length, reaching half way across the river.

Perry, in his work on Dagenham breach, proceeds to explain how this sullage driven into the river was deposited at the mouth of the breach, and above as well as below it, in the reaches of the Thames. He remarks that the deposit had been particularly detrimental to Erith Reach; and that even in Woolwich Reach, as he had been informed, the depth of water was lessened. All breaches, he observes, must be attended with a considerable flow of sullage into the river. After mentioning breaches that had occurred before his time, including one in the levels of Dagenham Beam, not three years and a half since, and several near Dagenham since he had been concerned there, he says, he attributes all such breaches not to any damage from the tides washing down or running over the tops of the banks or walls, but to the bad workmanship, decay, or defect of the sluices or trunks which are made for the drain of the levels, &c.; and he alludes to sluices made of wood as a prevailing custom in England, and as generally insecure and unskilfully placed. He recommends, therefore, a law to oblige all sluices on the banks of the Thames to be made with stone, cemented with tarras. The reasons why they have not been made so, he thinks, are, first, that men in England are not very willing to depart from the way of their fathers; and secondly, the matter of foundations. He argues, however, that if the foundations were constructed after the manner of buildings in Holland, the sluices might be formed of stone, or a sort of brick, as in Holland and Flanders, and might endure thousands of years.

The greater portion of the land bordering on the Thames, including the south of London, indeed, from Richmond to the Nore, is below the level of high-water, and reclaimed by walls varying but little in their construction, the general character of which is an embankment, the face of which is puddled with clay to a slope of 2½ to 1, and protected from the wash of the sea by a stone face. In some cases, where the steepness of the bank necessitates a greater slope, the face is stepped, and at each step a row of stakes driven to keep the stone facing in place. In constructing these walls, a grip about 6 feet deep and 6 feet wide is cut into the marsh to be reclaimed, on the site of the wall, and puddled before the bank is made, to prevent percolation. These walls and the necessary sluices for drainage require careful watching, for any portion failing would cause a catastrophe equal to the Dagenham or Middle Level inundation. The extent of these walls or embankments is very considerable.

It is a very remarkable circumstance that the marshes on the river side of the walls still unreclaimed, and termed "salt marshes," are invariably at a level of high-water, whereas the land reclaimed is generally 5 feet or 6 feet below that level. Whether the constant action of the tide raises the land subjected to it, or whether the absence of that influence allows the level of the marshes to subside, or whether it is due to both these circumstances, is a fit subject for discussion; but, be it as it may, there is no question of the fact that they do so exist.

Another material point for discussion is furnished by the supposition that failure had attended the attempt to stop the recent breach, and that the waters had regained possession of their old territory, some 7 feet deep at high-water over an area of from 3000 to 4000 acres. Assuming this to be the case, the breach would be rapidly widened and deepened, and, were the old system adopted, the reclamation would occupy many years. It would be a work of from three to four times the magnitude of the Dagenham reclamation; and on the authority of Lambard, the land inundated by the breach which occurred in 1527, near the recent breach, as before noticed, was not all reclaimed in sixty-three years.

HOBART TOWN WATER WORKS.

The important undertaking for ensuring to the inhabitants of Hobart Town and the shipping of the Port an ample supply of pure water is approaching completion. The original plan of the works was furnished by Mr. Gale. When that gentleman relinquished office, Mr. Bastow, who had been employed under him, continued in office, but he was succeeded by Mr. Grey, the present engineer. The foundation stone of the tower forming part of the works was laid on March 6th, 1861.

There are two main springs and several minor ones, brought along the race to a point at the east end of the Brown's River basin, which constitutes one source of supply; another is furnished by streams from two other creeks brought into the same basin. From the Brown's River basin, the water is brought into a receiving reservoir in wooden troughing, and from the receiving reservoir the water can be sent direct to town as pure as it comes from the springs.

In times of heavy rain there is not only sufficient to supply the wants of Hobart Town, but a considerable surplus. The estimate for a day's supply, allowing 30 gallons to each individual, is 600,000 gallons; this is an ample quantity, taking the population at 20,000; but the present engineer has known water to come down at the rate of 5,000,000 gallons a day. During the last summer the smallest quantity that came down in any one day was 362,880 gallons, or upwards of 18 gallons to each person. The works include a receiving reservoir and a storage reservoir, a dam, flood-gates, a valve-house, and a by-wash.

The receiving reservoir is a building with two divisions, a little above the storage reservoir; this building is 30 feet by 15. The water comes into the western side, and thence flows over into the eastern side, the two being supported by a mid-wall. Provision is made for straining the water, in order to intercept leaves, small vegetable and insect matter. After the water has passed from the west to the east of the storage reservoir it goes to town through a 10-inch iron main.

If there be a greater quantity of water than the main will take, as in the event of floods, it overflows from the receiving reservoir to the storage reservoir. Near the foot of the outer slope of the storage reservoir the valve house is placed. Valves are connected with the storage and receiving reservoirs, so that the supply can be taken from either source; and the main (10-inch) is continued from the works to the distributive reservoir at the top of Melville-street. Flood gates are constructed at the end of the storage reservoir, and for the purpose of admitting water into it, if desirable. Beyond the flood gates a dam is placed, convex to the stream, with openings for the passage of the water, the object of the dam being to intercept trees or anything heavy brought down by floods, and prevent their striking the flood gates. At this point there is a by-wash, that is the creek is diverted along the south shore of the reservoir, extending as far as the bridge to Gillon's quarry.

The storage reservoir is about 4½ acres in extent, and is estimated to hold 40,000,000 gallons of water. It was originally formed by throwing an embankment across the valley, in the centre of which is a puddle wall, the inner and outer portion being of earth. The wall is supported with earth on the inside and outside, sloping 3 to 1 on the inside, and 2 to 1 on the outside. The tower is erected near the foot of the inner slope; in the tower are placed the valves, so that when the sources of water from the springs are insufficient to supply the town, the valves are opened, and the reservoir is brought into use.

After the works had proceeded to a certain extent the then engineer, Mr. Gale, was anxious to test them; he therefore took advantage of a flood which came at that time, and opened the floodgates admitting the water into the storage reservoir. After the water had been in the reservoir for two or three weeks, symptoms of leakage were observed on the north-east side of the bank, to such an extent as to render it desirable as a matter of safety to withdraw the water from the storage reservoir. Mr. Gale about that time relinquished his connection with the works, and Mr. Joseph Brady, an engineer of Victoria, was consulted; that gentleman having visited the works proposed that a trench should be cut parallel to the foot of the inner slope of the bank, going down the rock and extending from side to side of the storage reservoir; and that the inner slope of the embankment should be stopped, that the trench should be filled with puddle, and the puddle continued up the slope to the top of the bank. As these and other additional works involved an expense beyond the original sum the corporation were empowered to borrow, a further Act of Parliament was obtained authorising them to raise an additional sum of £10,000. The proposal of Mr. Brady was adopted, and the works carried out by Messrs. Anderson, Shields, and Co., whose contract for the purpose was accepted October 19th, 1863. Some variation from Mr. Brady's plan was suggested by Mr. Grey, namely to place broken metal on the puddle to prevent the sun and the wind from acting on and cracking the puddle; and in order that the water from the reservoir might not wash over and beyond the puddle and undermine it, to lap the puddle over the top of the bank, so as to carry any water clean away; and stone pitching was placed on the broken metal, instead of puddle as proposed by Mr. Brady. In order also to prevent the water from washing over the tops of the bank, there is a raised border of stones set at right angles to the inner slope, so that in the event of waves caused by heavy winds working down the valley, the water might be kept within the inner slope.

It was originally intended to take the water from the storage reservoir through the valve house to town by a pipe laid through, and at the lower portion of the embankment, between the storage reservoir and the valve house, but when the weight of water came on the pipes (14-inch) they broke. An effort was then made to drive a drift from the east foot of the embankment, but it was unsuccessful. The object of the drift was to get to and be able to repair broken pipes; but as the attempt did not succeed it was abandoned, and the opening was filled in. Recourse was then had to a syphon; but during the repairs to the storage reservoir it was found desirable to dispense with the syphon and drive a drift, which was done. A drift was driven through from the east side of the embankment to the tower, and lined with timber. At the east of the drift a culvert was built to support the foot of the embankment; and a proposed extension of the south wing of that drift is to form one side of the proposed by-wash. A portion of the other side of the proposed by-wash is also built from the valve house 50 or 60 feet upward.

By the action of the flood of June in last year, the lower portion of the by-wash failed, and it is now proposed to bring the water down in a new course past the valve house in a more direct manner, the works to be of a substantial character.

A waste weir is also to be constructed, to be executed in a manner similar to the inner slopes of the embankment, puddle upon steps of earth, covered with broken metal, on which stone pitching will be laid. The estimated cost of the work still required is very moderate. Messrs. Anderson, Shield and Co.'s contract, with extras for certain repairs, amounted to £6,862: and he total cost of the work done, and proposed to be done, will exceed the £60,000 authorised to be borrowed, but the surplus will, probably, be paid out of the rates, without a further loan. When, however, the waste weir, the by-wash, and the sloped embankment down to the valve house are finished, the Water Works as a whole will be a credit to the city, and to those who, in spite of difficulties, shall have helped to perfect so necessary and so useful a scheme.

APPLICATIONS OF GEOLOGY.

Of all sciences geology has, perhaps, more than any other, been assailed as altogether an unprofitable study. A knowledge of the depositions of various rocks and strata, their relative ages, and calculations respecting the probable age of the world, has often been considered as practically worthless; while the discovery of the existence on the earth, at periods far antecedent to the creation of man, of varieties of animals that have become extinct, has been looked on by many with doubt and suspicion, because it was regarded as opposed to the Mosaic account of the creation. Geology has, therefore, had to struggle in its progress not only against the assaults of ridicule, to which most sciences are exposed, but it has had to encounter the still more formidable weapons of bigotry. It has fortunately made a triumphant stand against both. It has so far succeeded in overcoming the objections of the ministers of religion, that geology is now enlisted by them in support of the fundamental doctrines of Scriptural truth, and it has vindicated its utility by numerous valuable applications. For the purpose of bringing before the public, in a familiar manner, some of the practical uses to which the science of geology has been applied, the council of the Society of Arts decided to apply a portion of the proceeds of the property bequeathed to them by the late Dr. Cantor to the delivery of a series of lectures on practical geology; and they appointed Prof. Ansted as the expositor of the subject. The lectures were delivered during the session 1864-5, and they have just been published in an expanded form. We have only time in our present number to draw attention to this valuable contribution to practical science, which comprises, among other matters interesting to our readers, notices of springs and water supply, of cements and artificial stones, and of stones used in construction. We shall give a more extended notice of the work in the next number of the Journal.

PREVENTION OF RAILWAY ACCIDENTS.

TO THE EDITOR OF THE CIVIL ENGINEER AND ARCHITECT'S JOURNAL.

Sir,—I find some important remarks upon the above subject at page 195 of your last number, and beg to extract one of your statements, and add a little thereto. You say that each train ought, as far as possible, to be provided with means of "self-protection." In that sentiment I presume all will agree with you. The professed difficulty, however, upon the part of railway directors has been, that there has not, up to this time, been produced a practical means of meeting the requirements of the case, and not liable to be improperly used by nervous or mischievous persons, and which might not be the means of producing greater calamities than they were calculated to prevent. However that objection may have applied to other plans, I am not prepared to show, but I submit to railway directors that the following plan will meet one requirement. I quote from the catalogue of the West London Exhibition, Floral Hall, Covent Garden, No. 760:—

"Intercommunication for the protection of passengers while travelling on railways.—This is to be effected by cutting the seats in the existing railway carriages, and causing them to lift up, like seats in the pews of churches; or the part of the seat which is cut the breadth of the doorway can be affixed to the door, and so move with it. The doors at each end of the carriages will be, in part, glass. The doors, as between the compartments, would be, in part, perforated zinc. The plan is thus observational, conversational, and communicational, applicable to existing railway carriages, at a light expense, and by which passengers are enabled to protect each other. The guard can also be communicated with by atmospheric tubular arrangement, and the tickets collected while the train is in motion."—I am, &c. G. B. Galloway.

9, Margaret-street, Cavendish-square.

Examples of Building Construction, No. 75.—(Simpkin & Co., London.)—In this number there are several very excellent examples, which may be examined with advantage to the architectural student. We would notice those devoted to the upper portion of the tower of the New Town Hall, Bromley, built from the designs of Mr. T. C. Sorby, architect. The details of two of the doorways to Wigan and Cosher's hop warehouse, in Southwark and Great Guildford street, are bold, striking, and effective examples; and the chimney-pieces from several buildings, designed and executed by Mr. R. J. Withers, are neat, effective, and inexpensive. Altogether we look upon this addition to this useful work as calculated to keep up its high reputation.

WANTED: A NEW SOCIETY OF ARCHITECTS!

The gravity, and peradventure the patience, of our readers will most likely undergo a rude shock, on their merely glancing at the title of this article. "Surely," some of them will exclaim, on seeing it, "there is no lack of architectural societies in this kingdom: we have in London alone the Institute of Architects, and the Architectural Association; and in the provinces there are the Architectural Alliance, the Manchester and the Liverpool Architectural Society, and the Bristol Society of Architects; to say nothing of the Ecclesiological Society, and the legion of diocesan and archæological societies, established all over the kingdom."

All this, gentle reader or readers, is unquestionably true; and yet, before we lay down our pen, we hope to demonstrate that there is something wanted still. The Institute of British Architects is very well in its way; but laudable as have been its late efforts for the advancement of architecture and its professors, it makes no way with the general body of architects; and indeed, may be deemed, with a few exceptions, to be mainly a mere club of London architects, to whose round table all comers, who may happen to be unexceptional citizens, willing to pay two or four guineas a year, are eligible, without any competitive examination whatever. It is, in fact, a chartered club of gentlemen, who are willing to pay so much per annum for the pleasure and improvement derivable from social intercourse; or for the gratification of adding I.B.A. to their names, and yet keeping aloof from their fellow-Fellows and Associates all the year round; as more than half its members do.

That, practically, the Institute does not answer the intention of its originators, and give promise of really becoming a club of *British* Architects, was seen by a correspondence that, about a year ago, occurred between its then President and the Secretary of the Architectural Alliance, who coolly proved that, in number of architects practising all over the kingdom, the Alliance greatly outshone the Institute: and yet the Architectural Alliance is a thing of yesterday compared with the Institute; and is, moreover, an unchartered body. We do not pause to inquire the cause of this anomaly: we wish to proceed further; and say that, neither the Institute nor the Architectural Alliance are as useful to the public and the architectural fraternity as they might be. As to the Architectural Association, it has accomplished great things for architectural students and architects—we allude to it with respect and esteem; but, for the purpose we shall presently unfold, it is even worse than the two other societies named: its members are continually coming and going; so that, at the present time, were the odd score or so of its original promoters, most of whom are living, to enter its rooms in Conduit-street, and join in a debate, the present members, who will themselves part company in a few years, would open their eyes and mouths, and straightway inquire, "Who is that old fogey, who has risen to speak?" The Association is, in plain terms, nothing but a nursery; —and a very fair nursery it is. To become a permanent institution, or focus of professional authority, its nature and constitution would require remodelling *in toto*. A new member (generally a young student) enrols his name on the Association; listens to the papers periodically read by the members; reads a paper himself—perhaps half-a-dozen papers,—and then passes out of the society, to run his course, either as an architect unattached to any society at all; or, if he is doing well in the world, to figure for a few years as a member of the Institute, and ultimately be "laid up in lavender" on the muster-roll of that very safe, easy, and comfortable society. People can't always be reading papers at the Institute, or at the Association; or anywhere else. Architects grow bald and grey, which is nothing; but they attain to an active practice, which is something; and for this they cut reading papers —nay they do more: they refuse to bear high office, and to sit in the presidential chair *to hear them read*.

Nor is this discouraging state of things confined by any means to the Institute of British Architects; it has been, or will be in the long run, the normal condition of every society of architects, both metropolitan and provincial, whose main province is the mere reading and discussion of periodical essays, and the giving of *conversazioni*. These things are well enough in their way, but they are better fitted for the many amateur architectural and archæological societies than for an Institute of Architects; and, with all deference be it said, such things are not only better suited to, but they are better done by, amateurs than architects. In proof of this one need only look over a volume of Transactions of, say the Royal Institute of Architects, in which the essays contributed by amateurs play so considerable a part.

We have said these periodical readings, &c., constitute the main province of the Institute, and of the various other societies of architects; nor can it be said that the other tasks to which the members devote themselves can be fairly regarded as anything beyond exceptions to the general rule. The general rule holds good; notwithstanding the praiseworthy students' examinations of the Institute, the useful class of design of the Association, and the pleasant archæological trips of the Liverpool Architectural Society.

The Institute, and the other societies in question, have undoubtedly done very much to popularise architecture; but so has the Ecclesiological Society, and so have the many other societies of amateur architects.

Now, what we ask is this,—Can architects themselves do nothing more to elevate themselves and the practice of their profession than club together, as do even amateurs, for the reading of papers and the giving of occasional "spreads," or *conversazioni*? Is it not a fact in this year 1865 that, notwithstanding the Institute and the other societies, any man may call himself an architect; keep aloof from all these societies; get clients; practice as an architect, and boldly defy anyone to prove (what may be an unquestionable fact) that *he is no architect at all*. If this be the case, which no one can deny, what is the real intrinsic use of a man being a fellow or an associate of the Institute of Architects? The two titles or degrees indicate nothing whatever, save that their possessors are men well to do in the world, or at least capable of subscribing a certain number of guineas a year. The Institute has done some good in its day; albeit by dint of much "pressure from without;" but certes, it annually does a deal of harm; if in nothing more than this,—it jumbles up the capables and the incapables of the profession in truly mischievous chaos; elevating plain Dick So-and-so, who has a little money and a seven-year-old brass plate ("*Mr. Richard So-and-so, architect*") to an ostensible level with every eminent architect on its roll of Fellows: *e.g.* Sir Charles Barry and Prof. Cockerell were both Fellows of the Royal Institute of British Architects; *so is Mr. Dick So-and-so.* Nay, this is not all; he is a greater man by far, and a more eminent architect altogether (for is it not written in the chronicles of the Institute?) than yonder gifted, travelled, experienced man on the back benches, architect of more and finer public edifices than Mr. So-and-so can ever hope to erect in his whole life; for he, sitting behind Mr. Dick, is nothing more—"'pon my honour"—than a paltry Associate of this admirable Institute.

> Seven years' practice makes a Fellow:
> "The rest is—leather and prunella."

How can anyone, who reflects on this degrading feature of the constitution of the Royal Institute of British Architects, wonder that more architects do not enrol themselves members of it? How can its council complain with justice that our practising provincial architects for the greater part withhold their names and their influence from a society—chartered, indeed, and capable of better things—which remains to this day, and bids fair to remain for many a day to come, a mere social club of London architects? The term, "British," is purely imaginary and fallacious. To merit it, the Institute requires reforming altogether. Failing this, there is unquestionably "*Wanted, a new Society of Architects.*"

SOLOMON SET-SQUARE.

CONGRESS OF THE BRITISH ARCHÆOLOGICAL ASSOCIATION.

THE annual Congress of this Association was held last week in the city of Durham. Though at such a distance from London, nearly all the principal metropolitan members were present, including the venerable treasurer, Mr. Pettigrew, Mr. E. Roberts, Mr. Gordon Hills, Mr. Planché, Mr. Thomas Wright, and Mr. Halliwell. The number of local associates who joined the Congress was unusually large, especially ladies, and at the public dinner on Monday, the 21st. ult., there were mustered in the fine hall of Durham Castle at least two hundred. The proceedings commenced the same afternoon in Bishop Cosin's library on the palace green, which was crowded. According to usual practice the president of the previous year, Mr. Tomlin, M.P., ought to have been present to resign the office to his successor, the Duke of Cleveland, but he deputed Lord Houghton, who was president at the Congress at Leeds, to discharge that duty. There was nothing remarkable in the speeches nor in the inaugural address, and the only thing worth notice at the public dinner in the evening was a passage at arms between the Bishop of Durham and some of the officers of the Association. The Bishop, a short time ago, gave offence to the Archæologists by an alteration which he had made in a piscina in the cathedral, the bottom of which he had cut out and filled in with a solid block of stone. At the dinner on Monday the Bishop, in responding to the toast of the Bishop and clergy of the diocese, took occasion to give a rap at the archæologists for sometimes riding their hobby too hard, and admiring objects simply because they are old. He alluded to the church at Darlington, which he said had been disfigured in the recent restoration by the retention of an old arch which was very inconvenient, and rendered it nearly impossible to read the communion service at the communion table. That arch, so far from being an object of beauty and interest, was a very poor pattern of a very ugly period. The passion of archæologists for things that were old, he observed, reminded him of a banquet he once attended in his youth, when an enthusiastic geologist invited him to partake of a jelly made from fossil bones, as a dish of surpassing excellence, because of the antiquity of its material. This joke was certainly ill-timed, and it called forth a response in defence of the archæologists from Mr. Gordon Hills and Mr. Edwards. The Bishop was, indeed, mistaken in the main point of his accusation, for the arch at Darlington church was not retained on account of its antiquity, of which it has not much to boast, but on account of its utility, for it was found impossible to remove it without endangering the tower which it supports. The Bishop, however, made amends for his unfounded attack and for his ill-timed joke by giving the members of the Association and visitors a hospitable entertainment at his palace at Bishop Auckland, on Saturday. Feasting and excursionising too much occupied the attention of the Congress, to the neglect of the legitimate objects of the Association. Every day there was an excursion somewhere, and on four of the days the excursions were planned with a view to being entertained by some liberally hospitable hosts. On Tuesday they were sumptuously treated at the Roman Catholic College at Ushaw; on Thursday the Duke of Cleveland entertained them at Raby Castle, and he and the Duchess won all hearts by the very kind manner in which they studied the comfort and gratification of their visitors.

On Friday Mr. J. Hodgson Hinde treated the members at Newcastle, and on Saturday, as already mentioned, the Bishop of Durham welcomed them with good cheer at Auckland. It must be stated, however, that the excursions were not limited in their objects to feasting, though not a few of those who took association tickets confined their excursions to the places where the entertainments were provided. Among the objects of archæological interest visited and described on the spot were Lumley Castle, Chester-le-Street, Lanchester Church, Finchale Priory, Barnard Castle, Staindrop Church, Tynemouth Priory, the Friars' Monastery at Newcastle, the Roman wall and Museum of Antiquities in that town, and Brancepeth Castle and Church; nor must it be omitted to state that one morning was devoted to the inspection of the cathedral and monastic buildings of Durham, under the guidance of Mr. Gordon Hills.

The paper on Raby Castle, read by Mr. Hodgson within the castle, was one of the most interesting, and the slashing manner in which he attacked the modern innovators, who have entirely destroyed the ancient beauty of the interior, was quite "refreshing." The description, by Mr. Hills, of Durham Cathedral, and of Finchale Priory, by Mr. Roberts, formed also important features of the Congress. Mr. Thomas Wright brought the excavations at Wroxeter before the notice of the Congress on Friday evening, stating what had been discovered among the ruins of the ancient Roman city of Uriconium, and what are the prospects of further discovery, for prosecuting which it is intended to apply for a Parliamentary grant. The proceedings were brought to a close on Saturday evening, by a soirée in the magnificent new Town-hall, where the members and associates were entertained by the mayor and corporation.

Mr. Hodgson's paper on Raby Castle, and that by Mr. Hills on Durham Cathedral, will be found in another part of this number of the Journal.

UNDERSUNK FOUNDATIONS.

Timber piles are eminently unsuited for India, as they are soon destroyed by white ants. Iron, until very lately, has never been much used on a large scale, but undersunk foundations of brickwork have been in use for a very great length of time. The natives were in the habit of making them in a very primitive way. The ground was cleared and excavated as deep as possible without using shoring. The curbs consisted of a ring of basket work, or rough timber in some cases, on these masonry cylinders were built, ordinarily of splayed bricks laid in liquid clay mortar. When this reached a convenient height it was bound together with hay ropes. The well-sinker then got inside and excavated the earth from under the curb, until the cylinder sunk to its whole depth; a further portion of cylindrical wall was then built and sunk in the same manner, divers being used when the curb descended below the surface of the water; sometimes a contrivance called a jham is used, by which the earth is lifted, but it is of little use in any but sand foundation. When the wells were sunk to the necessary depth, they were slabbed or planked over, according to the material to be procured. In the Madras Presidency, wells for foundations have been constantly used. The Vellore Annicut was so founded, as also St. Andrew's church, built we believe in 1818.

When the East Indian Railway was being constructed it was found necessary, or rather advantageous, to use these brick cylinder foundations. European engineering skill made the following improvements on the native method of making and sinking. The curb was carefully made of strong timber bound together with iron, the section showing a wedge end downwards; vertical iron ties joined it to the brickwork, and prevented a separation. At certain heights rings of iron were built into the brickwork, and vertical ties passed through them, thus binding the whole together and preventing one portion of the brickwork from falling away from the rest, a disaster likely to occur without this precaution in quick and shifting sands. Again, where the iron rings were placed, cross horizontal ties keep the brickwork together and prevent the wells from bursting; when these had been sunk to the full depth required they were domed over, or corbelled out and in, to squares arched over, and arched over also from one to the other.

In the Jumna bridge the wells were partly filled with concrete and then built in with masonry, and not arched over at all, but we prefer the latter system, but it is often advantageous to fill the wells with concrete, thus each forms a solid column; but in all cases we recommend that this filling should not be built upon, preferring to arch over from the brickwork. The brickwork of the wells should always be of the very best carefully-moulded and well-burnt splayed bricks laid in the best hydraulic mortar.

To clear out the soil from the interior, dredging machines are used with success, and can be seen at the Armenian Ghat, where Mr. Denham, the district engineer of the East Indian Railway, is sinking some wells for the new pier; these are sometimes worked by steam power. A spoon and clay cutter are also occasionally used. A new sand pump has been patented in England, and one on the same principle is now being made by Messrs. Marillier and Edwardes, the Indian agents for the patentee. The best means, in our opinion, of getting out the subsoil to lower the wells is by means of divers. These men work with much more accuracy and economy than any machinery can; wells are apt to get out of the perpendicular, and require careful excavation to get them straight again. Mr. Denham had great trouble on this account, we believe, with well No. 1 on the Howrah side, but overcame it. Indeed, this well is now sunk to a depth of 87 feet below rail level—perhaps the greatest known depth in the world—and great skill and engineering knowledge was displayed in overcoming the many difficulties.

We now proceed to make a few remarks upon the different considerations which guide us in designing bridges upon well foundations, the heads of which we enumerated in a former number—viz., 1. To sink the wells until they rest upon rock or other good substratum; 2. To sink the wells to such a depth, that there is scarcely any fear of danger from scour; 3. To make a continuous barrier above and below, with a platform between, through which the wells (on which rest the piers) are sunk. With respect to bridges built on the first principle we would premise that the following general rule holds good, when practicable, with wells as well as other foundations—viz. that when founding upon rock, no matter how hard, your masonry should be sunk at least 6 inches into the rock at the shallowest part, and at least 2 feet into the most tenacious clay.

When a good soil is found within a reasonable distance of the surface of a river bed, cofferdams are generally made use of, as in the case of the bridge over the river Adjai, one of the principal rivers of Lower Bengal, which was built in 1854-55 by Mr. Sibley, now chief engineer of the East Indian Railway in the North-Western Provinces. The cofferdam was in this case made in three bays for each pier, and was composed of brickwork blocks, with two pockets each, which were filled with puddled clay; between the blocks also it was made water-tight.

The only instance we know of a bridge built on this first principle were the land piers of the Kankan bridge at Kamptee, of which we will speak more hereafter. Here the wells were sunk through sand until they rested on sandstone rock, which shelved down at an angle of 30°. We fear these were not allowed to bite into the rock, as the appurtenances for assisting in doing this, viz., Siebe's diving dresses, were handed over to the Barrakur bridge, where the late Mr. Powell told us they proved most useful, indeed necessary.

The second principle of designing well foundations—viz., sinking them to such a depth as to obviate danger from scour, is the one which has been most extensively used on the East Indian Railway. Amongst the principal bridges may be enumerated the Soane, which is completed, and the Jumna, which is in progress. In the former the wells were, some of them, sunk to a depth of 60 feet, and in the latter they are being sunk to a depth of 43 feet.

We believe that in sinking one of the wells of the Jumna the ruins of an old well were found, which interfered much with operations. It is probable that an attempt had been made in former years to build a bridge on wells somewhere near the present site.

The third system of building on wells may be called the Madras system, as it has chiefly been used in that country. It consists of building a barrier or annicut across the river, by a line of continuous blocks above and below. In some cases the upper blocks have been only sunk some 4 or 5 feet, and the lower ones little more, between these two curtains is laid a platform of stone, and below the lower an apron is laid to prevent scour, a most needful precaution.

It it evident that at least one, and if possible both lines of barriers should be completed in one season. We believe that the Kankan bridge at Kamptee failed through this precaution not having been taken.

We are of opinion that the two barriers and the platform between and the apron below should all be built in one season, and be completed before a single well for the piers is commenced upon. In designing a bridge of this description care should be taken to ascertain that the banks are determined at the line of your barriers, and that the water will not possibly turn the flank of your continuous wall.

In the Kankan bridge above referred to, it was intended to sink the upper barrier 10 feet and the lower one 20 feet. The wells under piers also 20 feet. We have not been able to obtain any reliable information regarding the failure of this bridge. We think it a pity, as these things should have thorough ventilation, as a beacon for the future.—*The Calcutta Engineer's Journal.*

RABY CASTLE.

The following account of Raby Castle, by the Rev. Mr. Hodgson, was delivered at the Congress of the British Archæological Society.

Mr. Hodgson said that, rich as the diocese of Durham is in objects of archæological interest, it is pre-eminently so in the way of ancient fortresses. Differing very widely in their situation, size, character, construction, and historical importance, extending locally over its whole surface, and chronologically from the dim and mist enveloped days of the ancient Britons to the time of our English Nero, when the castle-building of the Middle Ages was at an end, they form, as may well be imagined, a most valuable and instructive series. Conspicuous in their foremost rank is Raby, now the grand northern seat of the Duke of Cleveland, but dear to archæologists as the cradle, the old ancestral home and heritage of the mighty house of Neville. Raby, pointing by its name to a Danish origin, is first mentioned in connection with King Canute, who, after making his celebrated pilgrimage over Garmondsway Moor to the shrine of St. Cuthbert, there offered it with Staindrop and the rest of Staindropshire to the saint. Bishop Flambard wrested the rich gift from the monastery, but restored it again on his deathbed. It continued in the peaceful possession of the monks till 1131. In that year they granted it for an annual rent of four pounds to Dolphin, son of Ughtred, of the blood royal of Northumberland. To him most probably the first foundation of the manor might be attributed. But whoever the original founder may have been, Dolphin's descendant, Robert filius Maldred, was at all events Dominus de Raby when early in the 13th century he married Isabel Neville, by the death of her brother the last of that line, and sole heiress of that great Saxon house of Bulmer, lords of Brancepeth and Sheriff Hutton. From their son Geoffrey, who assumed his mother's surname, the history of the Nevilles may be said to date. To his descendant, John Lord Neville, we owe the present castle of Raby. Broadly stated, the whole of the building bears the impress of one era, and seems the realised conception of a single mind. How far any portion of the old manor was retained, or to what extent its foundation may have influenced the present ground plan, cannot now be said. Compared with the work at Sheriff Hutton, however, we see a striking contrast. That magnificent structure, in after times the residence of his great grandson, Richard III., though a little later in date, was still being rebuilt by John Lord Neville, in part, at least, contemporaneously with Raby. The plan is there a very regular one, an oblong square, with four huge towers of the same shape at the angles, and a gateway in the east front. So far as internal arrangements go, there is not much to be learnt, but its huge square mass, stark and gaunt, shooting up vertically to a vast height, is as unlike Raby in all respects as anything of the sort can be. All things considered, it may fairly be concluded, that while some portions of the older fabric were incorporated with the new, Raby presents essentially the work and ideas of one period. Its particular value in the series, therefore, and that which distinguishes it from the rest of the larger castles, such as Alnwick, Warkworth, Durham, Prudhoe, &c., is this, that whereas they consist of Norman cores, which have, as usual, agglomerated to themselves a heterogeneous mass of buildings of a later date, following more or less the lines of the old walls of enceinte, we have, or rather had, in it a perfect example of a 14th century castle, complete in all its parts, without any appearance of earlier work or later alteration whatever. Nearly every one who mentions Raby points out the apparent weakness of its site. But though certainly not set on a hill, it had yet originally other means of defence of which no notice is taken —viz., water, which making the place damp, no doubt, and being found practically unnecessary, was drawn off. A careful examination, however, will show that it must not only once have completely insulated the castle, but towards the south have expanded into something like a lake. But the real defence of Raby lay beyond the mere circuit of its own walls and waters. They were to be found in the warrior spirits of its lords, and in the border castles of Roxburgh, Wark Norham, Berwick, and Bamburgh, which they commanded continuously as warders and governors, from the days of Robert Neville, in the 13th century, to the time of Queen Elizabeth.

Apart from the question of the site, the castle itself is of great strength, and skilfully disposed. The general arrangement is as follows:—First, the centre nucleus, or castle proper, consisting of a compact mass of towers connected by short curtains, and of which the block shape may be described as something between a right-angled triangle and a square, having the right angle to the south-west. Next a spacious platform, entirely surrounding this central mass, then a low embattled wall of enceinte, strengthened by a moat house and perhaps a barbican, as well as by numerous small square bastions rising from its exterior base, and then the moat. The south front of the castle being so amply defended by water, its structural defences were naturally less important. Quite unlike the other, it was, with the exception of the flanking towers at either end, nearly flat. The first, or western of these, called the Duke's tower, is very large and square, and of different heights, being in fact two towers laid together. Considerably in recess, a rather low curtain connected it with the end of the great hall, which, till lately, rose up, tower like, but without projection. Beyond, and nearly in a line, came another curtain, short but lofty, and then the wedge-like projection of Bulmer's tower, which flanked the whole towards the east. This tower, which commemorates Bertram Bulmer, one of the Saxon ancestors of the Nevilles, by two raised B's in the upper story, being somewhat of unusual shape—viz., a pentagon, formed by the application of an equilateral triangle to a square, has given rise to comments and conjectures of the wildest sort. In all the written and unwritten accounts it is thought to bear a striking resemblance to an ancient arrow-head. No Norman or Saxon towers of the same shape are known. Canute was connected with the place—Chester was a Dane, the Danes used arrows, and, sublime conclusion! the tower is Danish, and its builder was the Danish King. It is sad to destroy such a captivating theory; but architectural evidence is inexorable, and proves the whole tower, from "turret to foundation-stone," to belong to an advanced period of the 14th century. An underground passage, there is little or no doubt, extends from the substructure of this tower to a small blocked up doorway in one of the bastions of the wall of enceinte, above the lake, from which again there is reason to think another traverses its whole length westwards. They require exploring.

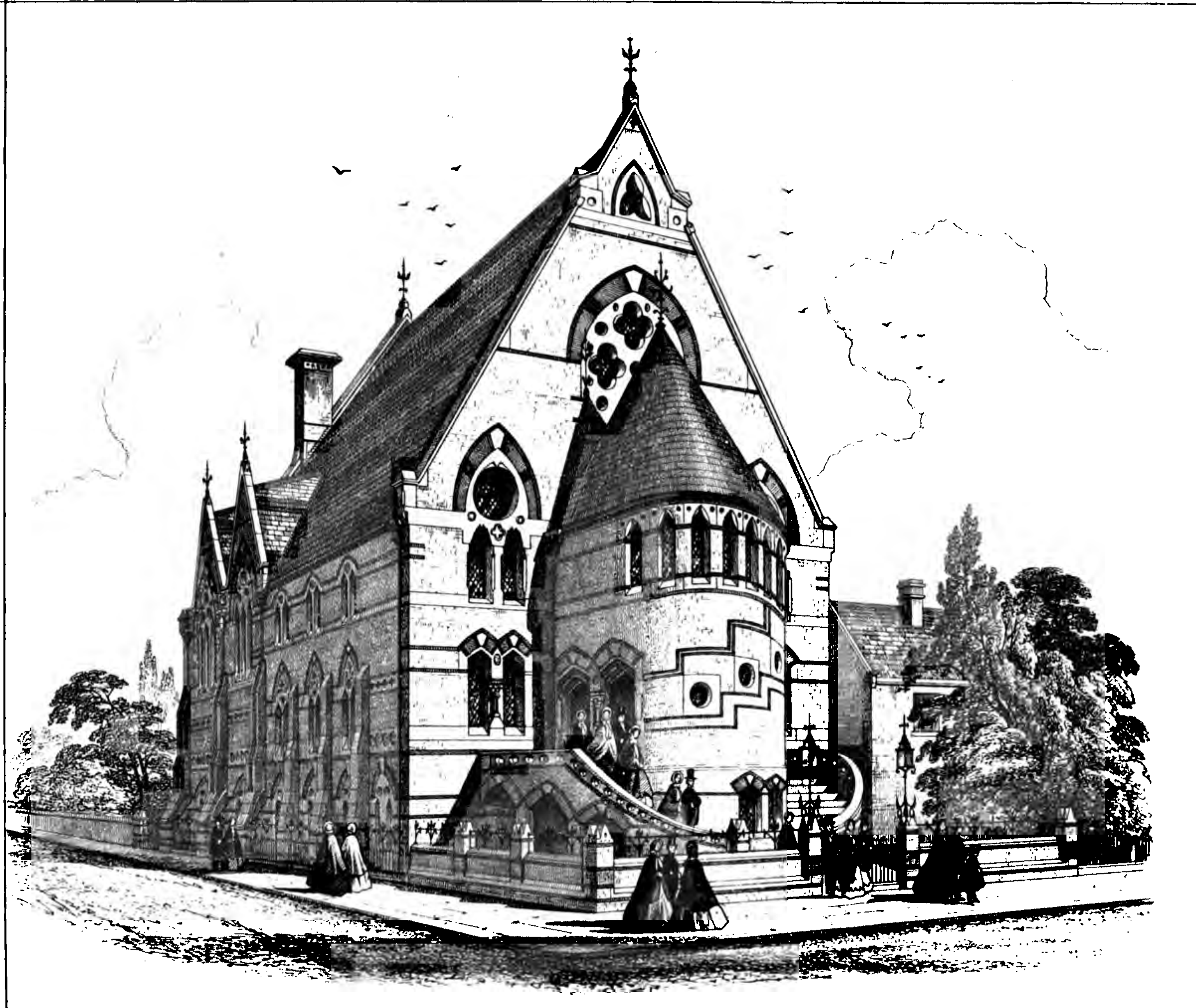
Passing onwards, we come to the east or north-east front. This is a very fine work, extremely bold and vigorous, set thick with towers, and broken by deep re-entering angles into immense masses. Thoroughly fortress-like and utilitarian in its character, without the least pretence of ornament, it is a masterpiece no less of artistic than constructive skill. Beginning at the south-east angle, we have, in the first place, the great pentagon of Bulmer's tower, and the short curtain spoken of as connecting it with the hall standing out transeptwise from the latter, and defending it to the east. A little further on, and about midway in its length, the chapel structure, terminating in a lofty tower, perform the same service. Projecting from the lower part of this tower, until destroyed in modern times, was an advanced portal. Again, at about an equal distance, a third transeptal mass, terminating in a tower called Mount Raskelf, stands out from and protects the hall. A short high curtain, extending between the chapel tower and this last, forms, at the same time, the limit of a small court-yard, and a screen to that portion of the hall which lies behind it. Mount Raskelf is the angle tower between what are, strictly speaking, the east and north fronts. Its northern face and curtain fall back deeply till they join the great square of the kitchen tower, which projects at right angles, and is connected by a strong machicolated curtain to the vast fabric of Clifford's tower, by far the largest in the castle, and of immense strength. This tower is planted with consummate skill. In shape an oblong square, standing almost detached, and set diagonally to the north and west fronts, it not only completely flanks them both, but also, from its close proximity to the moat house, could either lend it effectual aid in case of an assault, or render it, if captured, utterly untenable. Turning the angle of Clifford's tower, we gain the west front. A strong machicolated curtain, tending slightly westwards, connects it with a lofty tower of slight projection, and separated by a short wall space from the well advanced and diagonally-set turrets of the great gate-house. A deep recess in the elevation intervenes between the latter and our starting-point—the Duke's tower—which stands well out against and terminates the whole. Passing under the long vault of the great gate-house we reach the court-yard. Lofty walls close it on all sides with very picturesque and fine effect, the great hall lying to the east. A central tower of beautiful proportion which stands out at right angles to it shuts off a smaller court-yard to the north. The chapel, which is unquestionably the earliest part of the castle, and thoroughly fortress-like in character, determines by its date the period when the general work of reconstruction and fortification began. Taken by itself it seems to be about 1345. John Neville's license to fortify, however, was in 1379, while the great gate tower looks at least of 1430, and might be much later. It would seem at first sight most improbable that both the chapel and gate-house could be of one man's time, and yet I think I have satisfactory evidence that they are. The chapel, which looks much earlier than 1379, is, I make no question, really so. But what does that prove? Simply that it was built before the license to crenellate was taken out. The neighbouring estate of Witton affords a parallel example. There Sir Ralph Eure commenced his fortifications without a license, which, when granted, contained his pardon for so doing.

After pointing to several parts of the castle which confirmed his opinion, Mr. Hodgson proceeded to observe—We have proof, therefore, however unlikely it might seem at first, that both chapel and gate-house were built under one and the same man. Another most noticeable point about the work is the entire absence of buttresses. Every tower and curtain stands on its own unaided strength. The great diversity of design, especially as seen in the towers, should also be noticed. Without the least approach to affectation or extravagance in any, yet, of all the nine included in the central group, there are no two which bear the faintest resemblance to each other. This variety and beauy of proportion in its parts, and the admirable way in which they are combined, producing, as they did once, a sky-line perhaps unmatched in England, are really the glories of the castle. A perfect simplicity and directness of purpose, with infinite change and play of line, characterise the building throughout, and stamp it as the work of a master. Modern alterations have so obscured and destroyed John Neville's work in the interior that there is little of it to see. Still there is something. And altogther the castle, as completed by John Lord Neville, seems to have received no alterations of moment from any of his descendants. It continued their chief residence till 1570, the year of the rising of the North, when, for his prominent share in that unhappy enterprise, it was forfeited, with all the rest of his estates, by Charles the sixth and last Earl of Westmorland, of the house of Neville. Raby is simply without a history. A sudden suprise without bloodshed later, after its purchase by Sir Henry Vane, and a sort of attack later, when some lives were lost, but of which there is no account, sum up all its claims on that head. The only serious assaults it has undergone have been in modern times, and by architects. The wretched sash windows which disfigure the south front are due, it is said, to Inigo Jones. Compared with what has been done in more recent times, however, his work was harmless enough. The real ruin of the place was commenced in the last century, by making a carriage drive below the great hall and chapel. To carry out that scheme all the doors and windows of the lower hall were destroyed, its flat ceiling was removed, and a vile imitation vaulting substituted, which, by cutting off nearly 10 feet from the height of the great hall above, utterly ruined it also. So, too, with the chapel, which, in order to get an equal height in the sham vaulting, was positively cut in two from the bottom, while the advanced work beyond, with all its heraldry, was swept away entirely. And yet no terms of praise seem to have been too strong for this terrible mischief. Emboldened by it, our own day has followed suit. The great hall, already curtailed in height, has had, by the erection of a semi-octangular tower, in place of its original south end destroyed, full 30 feet added to its length, with what effect to its proportions may be imagined. Its grand old roof, which was pulled down at the same time, has been replaced by another, bearing no manner of resemblance to it, and simply infamous. In Bulmer's tower the magnificent vaulted roof was destroyed to get unnecessary height for some wretched bed-rooms. But the chapel has fared worst. A course of wanton, brutal havoc has swept away nearly everything ancient that it had. Though coped, all its window tracery has been torn away, the fine oak roof destroyed, the carved piscina bowl pulled out, the richly panelled western end as well as the sedilia obscured or destroyed, and the doorway, with the beautiful vaulted stairs leading to it from below, utterly annihilated. The work of the man himself, which is below contempt, needs no comment. Other things might be mentioned, but I forbear. It is painful to bear witness to such atrocities, but the interests of the noble owner, as well as those of art and archæology, require that it should be done. So far as Raby is now concerned, however, under the well-informed and enlightened rule of the present noble duke, I think I cannot do better than conclude by saying, in the words of the old motto of the house, "Esperance me comfort."

WESLEYAN CHAPEL, DALSTON.

(With an Engraving.)

The design from which this building has been erected was chosen from some half-dozen, submitted in private competition by as many architects. At the time the original design was made, and, indeed, till the completion of the working drawings, no side road was contemplated, and the front and interior were both designed on the expectation, that the side shown in the engraving, would be built up within a few feet; so that the side as it now appears was both designed and tendered for subsequently to the building proper, and was not to interfere with the front ele-



J R Jobbins

WESLEYAN CHAPEL, MAYFIELD TERRACE, DALSTON.

BAGGETT KEELING, ARCHT. VERULAM BUILDINGS GRAYS INN vation, nor the design and arrangement of the interior, as originally intended. The treatment adopted was owing, therefore, more to the original requirements than the circumstances as they exist.

The basement story, which is approached from the arcade under the steps to chapel floor, is but slightly below the ground level, and contains in the front portion four class-rooms, approached from either side of a wide centre corridor leading from the semicircular ended entrance lobby to the school-room, which occupies the centre of the building, and is at a lower level and more lofty than the class-room at the front and chapel-keeper's residence at the back. The dimensions of the school are 46 feet by 52 feet, and 14 feet high, and it has all the internal appearance and advantages of a room entirely above ground. A separate private entrance to the fixed platform at the back, is provided through a commodious committee-room, or vestry, which with a living-room the same size, and a bedroom and kitchen for the chapel-keeper, the coal-store and heating-room, occupy the back portion of the basement story.

The chapel floor is reached by two flights of wide stone steps, starting in the centre of and winding round either side of the apsidal projection, which forms the leading feature of the exterior, and indeed gives the key-note to both the design and arrangement throughout. This peculiarity of the plan and architectural effect has many advantages, and is far from being the offspring of mere whim and caprice. The accommodation, the cost, and the size of the building were all arbitrary. The number to be seated in the building necessitated all the space beyond the building line of the street being devoted to the chapel proper, and left no room for any internal lobbies or staircases; it became necessary, therefore, to centralise all such matters in as compact a form as possible, occupying as little ground space as might be out of respect to our neighbours' lights, and as little wall space as possible out of consideration for our own, which with the prospect of being built up on both sides, were of vital importance in the front. Once inside, any part of the building is in direct communication with the staircases and landings, which are entirely fire-proof in construction, wide and spacious, and while occupying a very small ground space, are ample and convenient from their simplicity.

The chapel (which, as the interior may form the subject of a future illustration, we will not further describe) affords accommodation for 1200 adults including the gallery; the minimum allowance is 20 inches, while the maximum for each person is 23 inches, the minimum width of pews is 2 ft. 8 in. and the maximum 2 ft. 11 in. from centre to centre.

The materials are externally, picked stock walling with yellow malms and white Suffolk discharging arches, with black and blue Staffordshire brick bands, all brickwork tuck pointed, the general dressings Bath stone, stone columns red Mansfield, slates, blue and red Bangor countess's, and the windows filled in with tinted rolled cathedral glass in three colours. The external lamps and finials are by Messrs. Hart and Son; the iron railing and gates by Mr. Lucy of Oxford,; the general contractors were Messrs. Dove Brothers; and the architect Mr. Bassett Keeling, of Gray's-inn. The original tender was £4000, the addition of ornamental side elevation, £135, and extra works introduced during construction, £100; making a total cost of £4235.

THE ATLANTIC TELEGRAPH.

The second attempt to make telegraphic communication between England and America has failed more completely than the first: for that cable, with all its faults, was stretched from shore to shore, and for two days messages were transmitted, though at a slow rate. The experience then gained, the increased knowledge respecting the conducting power of pure copper, the improved mode of insulation, the precautions taken in making the cable, and the greatly superior appliances to prevent accident in laying it, have proved of no avail; and it now lies broken and useless, two miles under water, in the midst of the Atlantic.

The misfortune is said to have arisen from circumstances that might be guarded against on another trial, and sanguine hopes are entertained that the broken end may be raised and spliced to the remaining portion still on board the Great Eastern, and thus, after all, the great object may be accomplished by the means already at command. We hope it may be so, but we do not see much ground whereon to rest confident expectation. Great care was taken by the conductors of the undertaking to prevent any reporters for the press from being on board to give an independent account of their proceedings; and the diary that has been published, written by Mr. Russell, former special correspondent of the *Times*, is admitted to be the account of a gentleman who is connected with the undertaking. It is no doubt reliable so far as it goes, but it omits several most important points on the accurate knowledge of which alone a sound opinion can be formed of the probability of success, even allowing the cable to be regained, and extended unbroken from Ireland to Newfoundland. Mr. Russell gives a very graphic description of what took place on board the great ship, and of the many incidents that occurred in paying out the cable, but he is silent altogether as to the rate of speed at which the signals were transmitted, and he omits to mention the condition of that portion of the cable that had been exposed to pressure at the bottom of the sea. The gutta-percha being compressible, it is natural to infer that at the bottom of the Atlantic it would be compressed into a smaller compass round the conducting core of copper wire, and that it would consequently be separated from the external wire rope. If that were so—and we are led to suppose it must have been, by the reported improvement in the insulation as the pressure increased—the strength of the cable would be greatly diminished by its separation into parts, and the stretching power of the external wire covering would be increased as compared with that of the core. It is important, therefore, to know what actually was the condition of that portion of the cable on which its strength mainly depended, and of that Mr. Russell says nothing. It is no less important to be made acquainted with the success of the attempt to increase the rapidity of the signals by adopting a plan that appears the reverse of that which a knowledge of the ordinary conditions of the conduction of electricity would seem to dictate. It is a well-established fact that the thicker the conducting wire the less resistance is offered to the transmission of electricity, and it seems most extraordinary, on looking at a section of the Atlantic cable, that the inner core intended to conduct the electricity should be so small. The reason for adopting so diminutive a conducting wire was this: when a wire covered with gutta-percha is immersed in water, and a current of electricity is transmitted, it becomes charged like a Leyden jar. The conducting wire serves as the inner coating of the jar, the gutta-percha acts the same part as the glass, and the water is the outer conducting coat. Such a wire, when of great length, if charged with electricity retains the charge for some time; in the same manner as a Leyden jar retains some portion of electricity after connection has been made between the inner and outer coating. Thus, when an electric signal is sent through a submarine wire, part of the electricity is retained by the gutta-percha, and obstructs the transmission of the succeeding signals, and some time is required before the wire is sufficiently free from electricity to enable it to do so. That was the cause of the slowness with which the messages were transmitted through the first Atlantic cable—the rate of transmission being about two words per minute. To increase the rapidity of transmission, it was proposed to increase the thickness of the gutta-percha covering; for as a thick glass jar cannot be readily charged with electricity, it was supposed that the thicker the gutta-percha compared with the size of the conducting core the less would be the degree of retention. That was found to be the case on making experiments with gutta-percha of various thicknesses; hence it was concluded, that by greatly increasing the thickness of the insulator, messages might be transmitted through submarine wires with little obstruction. The name "induction" was given to the retentive power of the gutta-percha, and by giving it that name great advance was supposed to be made in the knowledge of the subject. The question was unfortunately taken up by mathematicians, who discovered or invented formulæ for determining the proportionate thicknesses of the gutta-percha and the conducting wire best adapted to prevent "induction." The view of the subject of submarine telegraphy was thus completely changed. It became a question of charge and discharge instead of conduction, and it was considered that the best means of establishing rapid telegraphic communication was to diminish the conducting wire to the smallest size, and to increase the insulating coating. On that principle the two Atlantic cables were constructed. The strands of conducting copper wires were little thicker than common bell wire, their insulation was carefully provided for, and they were protected from injury by an external covering of wire rope, of which the insulator formed the core. The consideration of the conducting power and strength of the copper wire were entirely sacrificed to that of diminishing induction and increasing the rapidity of transmission; and it is most essential the public should be informed whether that object was attained, for as yet we are in ignorance of the rate of transmission so far as communication was maintained.

If the stretching power of the conducting strand of wires were not equal to that of the outer wire rope, it would have to bear a strain enough to break it at any moment, and we should like to be correctly informed whether the occasional interruptions to the communication, attributed to "defective insulation," were not, in point of fact, due to the rupture of some of the strands of the conducting wire. The necessity for perfect insulation is one of the bugbears of marine telegraphy. We have seen very distinct signals transmitted through entirely unprotected thin wire stretched through 100 yards of water. The thicker the wire the less would have been the quantity of electricity diverted from its course; and it is a problem we would submit to the mathematicians to solve: if an uninsulated copper wire one-sixteenth of an inch in diameter transmits electricity across 100 yards of water, what thickness should such a wire be to transmit signals from Ireland to America? At all events, it would be as profitable a speculation as the consideration of the minimum size of wire for such a purpose.

Ordinary knowledge of the property of conduction dictates that the principle on which an electric telegraph to America should be constructed, is that of making the conducting wire of the greatest thickness compatible with the flexibility required for laying it down. It was suggested by Mr. Bakewell, in a paper read at the meeting of the British Association, ten years ago, that the conducting wire of an Atlantic telegraph should be essentially self-protective. The only external protection it requires is near the shore, but at great depths in the ocean no external covering is necessary. A telegraph of that kind might be established at comparatively small expense, and it might be stretched across the Atlantic with much less difficulty than an elaborately fabricated cable. It might be covered with a sufficient thickness of gutta-percha to diminish the specific gravity to little more than sea-water, for it is not necessary the wire should rest on the bed of the ocean. A wire rope made of the purest copper, one quarter of an inch in diameter, well coated with gutta-percha, might, there can be no doubt, be extended to America without much difficulty, and if such a means of communication were formed, the electrical difficulty of transmitting signals through it—if any such difficulty were found to exist—would be soon overcome. At all events, such a plan is more feasible, more in accordance with the known facts of the conduction of electricity, and would be very much less expensive, than the construction of a complicated heavy cable, that can only be laid down in the Atlantic under specially favourable circumstances, and which depends for its action on the principle of charge and discharge, instead of on the conduction of electricity.

THE ROUND TOWERS OF CHURCHES IN EAST ANGLIA.

We have before us the last quarterly issue of the *Journal of the British Archæological Association*, dated 30th June last. This Journal, as many of our readers are aware, is admirably edited and illustrated, and always contains papers of great interest to the archæologist and architect. The part now before us embraces, among others, the second part of a paper by Mr. Gordon Hills, on the Antiquities of Bury St. Edmunds: by Mr. Planché, on the Earls of East Anglia: MS. collections relating to the County of Suffolk, by Mr. Wilton Rix: by Mr. Edward Roberts, on the Round Towers of Churches in East Anglia. Mr. Roberts' paper is peculiarly interesting, and we transfer it to our pages.

With the exception of eight detached instances, of which two are in Berkshire, two in Sussex, one in Surrey, two in Essex, and one in Northamptonshire, the whole of this class of towers exists in the east of England, and coincides exactly with the limits of the Saxon kingdom of East Anglia;* and although I am not about to suggest that, because these towers are all within those limits, they are therefore of the Saxon era, yet it may be that some national influence had been exercised upon these buildings by the descent of customs from the earlier to the later inhabitants; and the rarity of similar towers elsewhere, even though similar materials abound, and other materials are equally scarce, would lead to some such belief.

It has been remarked by Mr. John Gage,* that the materials of which these towers are constructed are local: that is so. But it is equally true of almost every Mediæval work, except in the important ornamental stones, such as Caen stone (for which the Normans appear to have had a reverence), and Purbeck and other hard, coloured marbles, in the earlier stages of Pointed architecture. There is, however, from the paucity of building stone in these counties, a singular exception, for all the early castellated and other large buildings have an almost universal use of stone from Barnak in Northamptonshire for the ashlar work. Its earliest use, however, so far as my own observation leads me, was about the year 1150 or 1160; and from its absence in these towers and the churches to which they belong, some conclusions may be drawn.

These towers, in some cases, are built entirely of flints, in others of flints mingled with the sepia stone. In some there are slight indications of the courses being laid herring-bone fashion, but no more inducing me to consider them Saxon than would the flints in modern walls, which are frequently laid at opposite inclinations. In all there are about one hundred and seventy-five of these circular towers in England, namely, one hundred and twenty-five in Norfolk, forty in Suffolk, and ten in other counties. I have prepared probably a nearly complete list of them; including some which have been destroyed.

In Surrey: Lower Tooting.

In Northamptonshire: Stanwick.

In Sussex: Piddinghoe; South Ease.

In Berkshire: Welford;† West Shefford.

In Essex; Great Leighs; South Ockendon.

In Cambridgeshire: Bartlow; Snailwell.

In Suffolk: Aldham, St. Mary; Ashby, St. Mary; Barsham, Holy Trinity; Bayton;‡ Belton; Blundeston, St. Mary; Bradfield (detached); Bradwell, St. Nicholas; Bramfield, St. Andrew (detached); Brome, St. Mary; Bruisyard, St. Peter; Bungay, Holy Trinity; Burgh; Fritton,§ St. Edmund; Frostenden, All Saints; Gisleham, Holy Trinity; Gunton, St. Peter; Hasketon, St. Andrew; Hengrave; Herringfleet, St. Margaret; Holton, St. Mary; Ilketshal, St. Margaret; Little Bradley, All Saints; Little Saxham, St. Nicholas; Lound, St. John Baptist; Mettingham, All Saints; Mutford, St. Andrew; Rickinghall Inferior, St. Mary: Risby, St. Giles; Rushmere, St. Michael; Southelmham, All Saints; Stuston, All Saints; Syleham, St. Mary; Theberton, St. Peter; Thornham Parva; Thoringham, St. Peter; Thorington, St. Peter; Weybread, St. Andrew; Wissett, St. Andrew; Wortham, St. Mary.

In Norfolk: Acle, St. Edmund; Appleton, St. Mary (a ruin); Aslacton, St. Michael; Asmanhaugh, St. Swithen (rebuilt 1842); Aylmerton, St. John Baptist; Barmer, All Saints; Bawburgh, St. Mary and St. Wolstan; Bedingham, St. Andrew; Beechamwell, St. Mary; Beeston, St. Lawrence; Bessingham, St. Mary; Bexwell, St. Mary; Brampton, St. Peter; Braudeston, St. Nicholas; Breccles, St. Margaret; Briston, All Saints (taken down 1724); Brooke, St. Peter; Buckingham (Old), All Saints; Burgh (ruin); Burlingham, St. Peter; Burnham Deep Dale, St. Mary; Burnham Norton, St. Magaret; Bylaugh, Virg. Mary; Catton, St. Margaret; Chippesby, St. Peter (ruin); Cockley Cley, All Saints; Colney, St. Andrew; Cranwick, St. Mary (said to be of the time of Harold); Croxton, All Saints (reconstructed in 1826 of the same materials); Dilham, St. Nichols; Earl Framingham, St. Andrew; Eccles, St. Mary; Edingthorpe, All Saints; Feltwell, St. Nicholas; Fishley, St. Mary; Forncett, St. Peter; Freethorpe, All Saints; Fritton, St. Catherine; Gayton Thorpe, St. Mary (with dome); Geldeston, St. Michael; Gissing, St. Mary; Gresham, All Saints; Haddiscoe, St. Mary; Hales, St. Margaret; Hardley, St. Margaret; Hardwick, St. Margaret; Hautbois (Great), St. Theobald; Haveringland, St. Peter (a ruin); Heckingham, St.

* They are, however, mainly in Suffolk and Norfolk, there being but two in Cambridgeshire.

* Archæologia, xxiii., 7.

† See Archæological Journal, vol. xvi. p. 242, for remarks on this church.

‡ Where the dedication s do not appear, it is in some cases because the churches are disused and ruinous, and I have been unable to ascertain the dedications.

§ Suckling, Hist. Suffolk.

Gregory; Hemblington, All Saints; Hillington, St. John Baptist; Horsey-next-the-Sea, All Saints; Howe, St. Mary; Ingworth, St. Lawrence (said to be of the time of Rufus,—fell in 1822); Intwood, All Saints; Keswick, All Saints (a ruin); Kilverston; Kirby Beadon, St. Mary (a ruin); Kirby Cane, All Saints; Letheringsett, St. Andrew; Lexham (East), St. Andrew; (West), St. Nicholas; Mautby, SS. Peter and Paul; Matlaske, St. Peter; Merton, St. Peter; Morning Thorpe, St. John Baptist; Morton, St. Margaret; Moulton, St. Mary; Needham, St. Peter; Norton Subcourse, St. Margaret; Norwich, St. Benedict, St. Ethelred, St. Julian (said to be founded before the Conquest), St. Mary Coslany, St. Paul; Pickenham, All Saints; Plumstead, St. Gervase; Poringland (Great), All Saints; Potter, St. Nicholas; Quiddenham, St. Andrew; Raveningham, St. Andrew; Repps, St. Peter; Ringstead (Great), St. Peter (church taken down 1771); Rockland, St. Peter; Rollesby, St. George; Roughton, St. Mary; Roydon, St. Remigius; Runhall, All Saints; Rushall, Virgin Mary; Ryburgh Magna, St. Andrew; Sedgeford, St. Mary; Seething, St. Margaret; Shereford, St. Nicholas; Shimpling, St. George; Snoring (Little), St. Andrew (detached); Somerton (West), St. Mary; Stanford, All Saints; Stockton, St. Michael (with a spire); Stody, St. Mary; Stratton, St. Mary (short spire—church said to have been rebuilt 1330); Surlingham, St. Mary; Sustead, SS. Peter and Paul; Swainsthorpe, St. Peter; Syderstone, St. Mary; Taseburgh, Virgin Mary (said to have been rebuilt in 1380); Taverham, St. Edmund; Thorpe next Haddiscoe, St. Matthias; Thorpe Abbots, All Saints; Threxton, All Saints; Thwaite, All Saints; Tichwell, St. Mary; Topcroft, St. Margaret; Tuttington, SS. Peter and Paul; Wacton, All Saints; Walton (East), St. Mary; Watton, St. Mary; Welborne, All Saints; West Dereham, St. Andrew; Wickmere, St. Andrew; Witlingham, St. Andrew (ruin); Witton, St. Margaret; Woodton, All Saints; Worthing, St. Margaret; Wramplingham, SS. Peter and Paul; Yaxham, St. Peter.

Octagon towers are not included.

I have more particularly gone through the dedications, because, had there appeared Saxon or Danish saints among them—it would have led me to make some research into those particular cases in order to ascertain if there had been earlier buildings to account for the popular belief in their Danish or Saxon origin. The dedications appear to be as follow: thirty-six to the Virgin Mary, twenty-eight to All Saints, seventeen to St. Andrew, thirteen to St. Margaret, nineteen to St. Peter, eight to St. Nicholas, four to St. John the Baptist, four to Holy Trinity, four to St. Michael, four to SS. Peter and Paul, two to St. Lawrence; and one or two each to St. Gervase, St. Giles, St. Edmund, St. Catherine, St. George, St. Remigius, St. Julian, St. Benedict, St. Gregory, St. Ethelred, St. Matthias, St. Theobald, St. Swithin, and St. Wolstan.

These are those in Norfolk and Suffolk, the others being in most respects very dissimilar.

Several local and other writers have hazarded conjectures on the subject of the dates of construction. Britton considered them Danish, and all writers up to Mr. Gage's time appear to have entertained no other opinion.

Until within forty years of the present time, all early round-arched work was called either Danish or Saxon. Mr. Rickman, in 1824, first attempted to promulgate the truth; but in doing so ran to the opposite extreme, and refused to believe in anything earlier than Norman. A more critical and exact study has since prevailed, and I believe we are now nearly approaching the real chronology of these works by a rigid comparison of records with the remains in existence.

We have seen how these towers came to be considered as Danish or Saxon. In 1829 Mr. Gage, then director of the Society of Antiquaries, endeavoured to dispel that popular delusion as regards these towers, which Mr. Rickman had been doing a few years before as regards mediæval architecture in general. In a clear and perspicuous paper he disposes of that part of the subject; and I have nothing to object to, nor to add to that communication, which has been printed;* but further observations and increased means of forming a judgment enable me to supplement that account. I have found that these towers, though varying from 7 ft. 7 in. internal diameter (Mettingham), to 19 feet (Wortham), have walls about 4 feet and 4 ft. 6 in. thick† with only one entrance, namely, at the east, and therefore from the body of the church. The windows, where they remain unaltered, are either small circular eyelets* or narrow loop-holes, with plain semicircular arched heads, pierced out of the stone, and mostly with chamfered edges. Other windows have been inserted at every age since; and also, with few exceptions, either the churches have been rebuilt, or have been attached to the towers. The upper stages also, or parapets, have been rebuilt, mostly octagonal. In only one instance, that of Fritton in Suffolk, have I found what I believe to be the type (nearly complete, though enlarged by aisles) of all these buildings; though the tower is not remarkable except for its dilapidation, the severe cracks being merely filled up with cement. The church has a nave and chancel of early form, 51 feet long internally, and 11 feet wide. This has since been widened to 21 feet; but the original was but 11 feet, as stated. The east end is apsidal, and very perfect. It has recently been restored with some care. One peculiarity exists here; and, so far as I know, only in one or two other churches. It is the "tapering" of the plan from west to east.† The chancel itself is vaulted, and also diminishes in height towards the east.

All the other churches are equally simple parish churches, such as were common in the Norman period.‡

The tower of Wortham Church is remarkable for its magnitude, and for the sets-off. In that of Herringfleet we have a tower which, in its whole height, appears to have more of the original than others. It has the Norman billet-molding, as well as a centre shaft to the window of the upper part. This window would in many cases be termed Saxon, even in the present day; but how a Saxon upper story, such as this, could have been placed on a purely Norman substructure, I am not prepared to say. There are instances, it is true, of earlier work with later work both beneath it and surmounting it. St. Mary's, Leicester, has the nave of Norman work, pierced below with twelfth century arcades, and with still later walling over the Norman;§ but a circular flint tower can scarcely have been underpinned in the same manner as a plain wall could be.

The conclusions then at which I arrive are these:—

1. That in most cases the churches have been destroyed or rebuilt, while the towers have remained.

2. That the towers were probably built by one class (or lodge) of workmen, and are all of nearly one age. They have precisely the same characteristics—similar in material, shape, and (with one exception) size; and are without staircases.

3. That they were built for use as bell-towers.

4. That they were erected about 1100 to 1150. If they were of earlier date—and no doubt there is very great difficulty in determining their date from the mere walling—I should have no hesitation in saying that all the towers had been originally detached, and that churches had been built against them; and that all the principal openings had been made subsequently to their first erection. I cannot say that I incline to this theory; but I see no alternative than to adopt one or the other of these views. I think I have given a correct explanation; but as rubble flint-work shows no marks of age, it is just possible that some of the towers may be of earlier date, without showing it, than that at which I have placed them; but in that case they must have been subjected to the several variations and additions I have named, and this I do not think probable to that extent.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1865.

The thirty-fifth meeting will commence in Birmingham, on Wednesday, the 6th of September, under the presidency of John Phillips, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. The general secretaries are William Hopkins, Esq., M.A., LL.D., F.R.S., St. Peter's College, Cambridge, and Francis Galton, Esq., M.A., F.R.S., F.G.S., 42, Rutland-gate, Knightsbridge, London; the assistant-general secretary is George Griffiths, M.A., Professor of Experimental Philosophy in the University of Oxford, 5, Park-villas, Oxford; the local secretaries for the meeting at Birmingham are

* Archæologia, xxxiii. pp. 7-17.

† Hengrave is an exception, having very thin walls, but it has been rebuilt, as is said, in the fourteenth century.

* Earl Framingham and Howe.

† Framingham Earl has a tapering chancel.

‡ St. Mary Coslany, Norwich, is perhaps the only exception; but as that church was rebuilt in the fourteenth century, it does not affect the assertion.

§ See Archæological Journal, vol. xix. p. 247, for a detailed description

William Matthews, Esq., jun., F.G.S., John Henry Chamberlain, Esq., and the Rev. G. D. Boyle, M.A., Christ Church-buildings, Birmingham; and the local treasurer is William Holliday, Esq.

The following are the arrangements:—The general committee will meet on Wednesday, the 6th instant, at one p.m., for the election of sectional officers, and for the dispatch of business usually brought before that body. On this occasion there will be presented the report of the council embodying their proceedings during the past year. The general committee will meet afterwards by adjournment.

The first general meeting will be held on Wednesday, the 6th instant, at eight p.m., when the president will deliver an address. The concluding meeting on Wednesday, the 13th, at three p.m., when the Association will be adjourned to its next place of meeting.

At two evening meetings which will take place at eight p.m., discourses on certain branches of science will be delivered. There will also be other evening meetings, at which opportunity will be afforded for general conversation among the members.

The committees of sections will meet daily, from Thursday, the 7th, to Wednesday, 13th instant inclusive, at 10 a.m. precisely. The sections will meet daily, from Thursday, the 7th, to Tuesday the 12th, inclusive, at 11 a.m. precisely.

Reports on the progress of science, and of researches entrusted to individuals and committees, and other communications intended for presentation to the sections, are expected to be forwarded in letters addressed to the assistant-general secretary, at Birmingham, previous to the meeting, accompanied by a statement whether the author will be present, and on what day, so that the business of the sections may be satisfactorily arranged. The reports complete, and concise abstracts of other communications, are to be delivered to the secretaries of the sections before they are read, previously to the close of the meeting, for publication in the 'Transactions.'

The following are the titles of the sections to which communications may be presented:—

Section A.—Mathematics and Physics.
Section B.—Chemistry and mineralogy, including their applications to agriculture and the arts.
Section C.—Geology.
Section D.—Zoology and Botany, including Physiology, subsection D.
Section E.—Geography and Ethnology.
Section F.—Economic science and Statistics.
Section G.—Mechanical science.

FINCHALE PRIORY, DURHAM.

At the recent Annual Congress of the British Archæological Association (reported in another part of this month's Journal), the members made an excursion to Finchale Priory, when Mr. E. Roberts, F.S.A., gave a very interesting description of the ruins, of which the following is a condensation.

Mr. Roberts said, that this Priory had always been called Abbey, by mistake. He would give a general description of the building, and then proceed to a description of the foundation of the structure, the subsequent changes which it had undergone, and compare the same with the condition in which they then found it. The situation was said to be second only to Fountains abbey and to Bolton abbey. The locality was one of remarkable beauty. The mediæval monks certainly had displayed the utmost discrimination in selecting such a site as that for their residence. St. Godric, the hermit, who founded the priory, led a very ascetic, rigorous life. After having been a sailor some time, he lived near to that place. He could not have lived exactly upon the spot where they were then met, but he did undoubtedly live somewhere in the neighbourhood, for sixty years and upwards, and underwent greater privations than other saints. So severe was his discipline, that he even mixed the flour that he used with ashes, and when it was made into bread he kept it for several months before he ate it, lest it should be too good for him. Mr. Roberts had great doubts as to the truth of some of the existing stories as to the practices of those ascetics. It appeared to him from the excellent book which had been published of the writings of Dr. Raine, who died a short time ago, that the priory was an excessively poor one. He found that for a series of years the expenditure exceeded the income, and that in one case—towards the end of the fifteenth century—the expenditure exceeded the income by as much as the income itself. He thought that he might offer this fact as the groundwork of the reasons which might be given as to why the church was diminished in size, because for several years—about the year 1360—there was a falling-in of the work near the arcades. For two years comparatively small sums were obtained and appropriated to the re-edification of the church and house. It seemed to him that the state of repair in which the aisles then were, induced them to take down the aisles and to use the material to fill in the arches, so as to save themselves the expense that would have been consequent upon the rebuilding of the same. No one had before offered any opinion upon that point; but he did think, after reading the rolls which extended over two centuries, that such a construction was the proper one to put upon the case, and he claimed for himself the credit of it. One writer offered his opinion that the side aisles were removed in 1436, when other alterations also were made. There was not the slightest doubt in offering this opinion that the alterations took place between 1360 and 1370. One very great regret which he had to express with regard to those ruins was that they had been converted into a fruitful quarry for the use of all persons in the neighbourhood. They had taken away the stones and used them in the construction of other places. For some time that practice was rigidly put a stop to, but he heard now that it was a recurring evil, and that the stones were being carried away in large quantities, and used in the erection of farm buildings in that locality. In this way the figures and sculptured stones had been removed, and he thought that it was desirable that the inhabitants of Durham should endeavour in some way to prevent such destruction of such a fine memorial of the past. Such destruction of the building was like the destroying of the books or MSS. composing a fine library, with the difference only that the destruction of the library was perhaps of less degree of consequence, as the works which it contained referred to a large number of sciences, whilst the carrying away portions of the remains of the priory deprived them of a monument which could not be replaced, and of information which they could not otherwise gain. There were a few portions of the church to which he would direct their attention. It consisted chiefly of a long and narrow nave with aisles. Some of those aisles on the north side had been destroyed, and the other had been converted into one aisle of the cloister. There was a long and narrow choir at the western portion. The conventual buildings were on the south side. The church and buildings were said to be an imitation of those at Durham, but he saw no resemblance whatever, except that there was a nave and transept, and so on. The ground rose rapidly from the river, but the building, instead of rising in proportion, had its floors raised to the level of the upper land. There were a number of such buildings made in that way in Italy, but he did not know of any other in England which was the same. That was a nice example of the manner in which the builders of that day accommodated their buildings to the land which they had to deal with, and suited their work to the place and materials. The date of the priory seemed to be about the time of Henry III. or from 1194 to 1200. He wished it to be understood that he gave that as his own opinion. Two of the pillars which supported the structure, it would be found on examination, were connected with the walls, whilst the other two were separated from them. Dr. Raine had said that the central tower, with its piers, was entirely added to the church. That was not correct. The arches were of later date. The keystone lay in the cottage close by, and could be inspected. Dr. Raine had fallen into another error in his description of the spire, by representing it other than of wood, an opinion supported by Dugdale. There was a short tower in the centre. The windows were lancet, and were rabbeted. They had not been glazed with glass, but inclosed by lattices. In the transept there were places for altars, one no doubt having been the shrine of St. Godric, to whom, with St. John the Baptist, the church was dedicated. The nave was wider at the west end than at the east, and became telescopic like the half of a barrel. In one portion of the recess there was a recess which had puzzled many. It puzzled him for a time, but he had satisfied himself that there was a shrine and ambrey.

THE GEOGRAPHY AND GEOLOGY OF PETROLEUM.*

By Albert Leeds.

The northernmost point on the American Continent at which petroleum has been largely found is in Canada West, at Enniskillen, near Lake St. Clair. The accounts of the quantities which have issued from single wells in this locality are too well authenticated to be doubted. In the year 1862, when Pennsylvania produced so much oil that its commercial value became too low to make it profitable to pump wells distant from a market, these Canadian wells were allowed to overflow with oil acres of ground. They became choked up by neglect, and it is but recently that they have been reopened and properly worked. Lying on nearly the same parallel are, to the eastward, Lockport, in Niagara county, New York, and Hamilton, in Canada, on the shores of Lake Ontario; to the westward, St. Clair county, Michigan. In all these localities oil has been found.

They constitute, in fact, a boundary line 200 miles in length, which limits the oil regions upon the north. Now, carry this line southward for 350 miles: it will stop near the source of the Kanawha River, upon the slopes of the Alleghany Mountains, in West Virginia. This tract, 200 miles broad, 350 miles long, and embracing 70,000 square miles, is at present the only region east of the Rocky Mountains where petroleum has been found in workable quantity. Now, if a diagonal be drawn from the north-east to the south-west corner of this tract, it will be seen: 1. That the Alleghany Mountains and the Blue Ridge Mountains are parallel to this diagonal. 2. That the general course of the Ohio and Alleghany Rivers is likewise parallel to it. 3. That all the rivers, creeks, brooks, and ravines where petroleum has been found, either in the valley-basins of those great rivers, or in the water-sheds which feed them, flow either parallel or at right angles to this same diagonal.

In concluding this short sketch of the geography of the oil regions, may it not be asked whether the great geographical fact stated above has not some intimate connexion with the geology of petroleum and the action of oil wells?

Everywhere throughout the world geologists have found that certain rocks which are similar in chemical nature, in physical characters, and in organic remains, are always found in the same relative position to each other. Any series of rocks thus allied is held to be the result of the same physical forces, and marks a distinct era in the building up of the crust of the globe, called a geological epoch. Such a group of rocks is called a formation. Deepest in the earth, and first in order in point of time, was built up a great group of rocks, all characterised by the absence of any trace of animal life. These are of unknown thickness. They underlie all other rocks, and man would have never known of their existence except for those mighty convulsions of nature which have rent asunder the earth's surface, and sent up through fissures or protruded from the craters of volcanoes the molten matter of these first foundation masses. Upon them rests a long series of sandstones and limestones of very varying thickness, known as the lower and upper Silurian systems. Another step towards the earth's surface brings us to the Devonian system, wherein we first find petroleum in the United States, and this, together with another great formation, called the Carboniferous, include all the rocks from which oil has been so far obtained in the regions above referred to.

But any description of the oil-yielding rocks will be unintelligible if it be for a moment supposed that the geological formations lie one upon another like the leaves of a closed book. Geology teaches that some mighty force, in ages long past, has operated from below in such a way as to bring up the edges of the lower layers of rock to the earth's surface. They would, therefore, appear to us like the edges of the leaves of a book, when the book was wide opened. And thus it happens that formations but two or three miles in thickness, may be stretched over hundreds of miles of the earth's surface, and that by beginning at some definite point and walking in the proper direction, we can review in detail the rocks which we wish to consider.

Let us take our geological sketch from the same point at which we took a bird's-eye view of the geography of the oil regions. Standing at Enniskillen, let us look far away to the southwest along the line of that diagonal to which I have already called your particular attention. At Enniskillen petroleum is found in the corniferous limestone which occupies the lowest point of the Devonian system. This corniferous limestone is composed in great measure of fragments of corals and sea-shells The cavities of these corals and sea-shells are often filled with liquid bitumen, and the inhabitants of those places where this corniferous limestone exists find the bitumen issuing in the form of tar from the kilns in which they reduce this rock to lime. According to an analysis made by Hunt, the chemist of the Canadian Geological Survey, specimens of this corniferous limestone yielded from 7·4 to 12·8 per cent. of bitumen, fusible, and readily soluble in benzole. Its thickness in Enniskillen is about 100 feet. Lying directly above the limestone is the Marcellus shale. Throughout this and the formation next to be described, there are many septaria or modular concretions highly charged with bitumen. This Marcellus shale is about 50 feet thick in that part of Canada lying between Lake Ontario and Lake Huron. And in the cavities and fissures of these two rocks, which in Canada are not above 150 feet in thickness, was stored up thousands of years ago those millions of gallons of petroleum hitherto found in Canada. But Lake Erie intervenes, and we must therefore cross over to Western New York if we wish to inspect the rocks in the same order as that in which we commenced.

The rocks which here yield petroleum are found in what New York geologists call the Hamilton group, which lie above the Marcellus shale and corniferous limestone in the geological scale. The oil springs in the vicinity of Lockport and along the banks of Chautauque and other lakes in Western New York, are mainly in this group of rocks. In fact, it was from Seneca Lake that the oil was brought which the Indians traded away to the early white settlers of Pennsylvania and New York, and it was by the tribe which inhabited the shores of that lake—the Senecas—that the use of petroleum as a healing ointment was made known. Petroleum was first sold in America by druggists, under the name of "Seneca Oil." Western New York is now being diligently prospected, and already Chautauque Lake is glowingly depicted in the prospectus of a new oil company. In the black shales which exist in the south-western part of New York, and which are known as the Genesee slates, no oil has yet been found. But where the same rocks reappear far away to the southwest, at Mecca, Ohio, they are found to yield a large supply of lubricating oil. We will put down the thickness of these rocks at 300 feet.

Proceeding further in the same direction, we find the shales and limestones of the Portage group, yielding oil from those wells on Oil Creek which have been sunk to the greatest depth. These rocks at Oil Creek are 1700 feet thick. Above this we find a long series of alternate slates and sandstones, the latter being sometimes replaced by limestone. If you take a drawing of the rocks in Venango county, wherever the quarryman has blasted away the hill-side, whether you look 400 feet above, or at the rocks just before your feet; whether you make the drawing of rocks along the Big Sandy, or up Sugar Creek, at Walnut Bend, along Oil Creek, or up Cherry Run, everywhere you will get a picture of thin argillaceous shales alternating with sandstones. If an accurate record of any well sunk in Venango county be consulted, it will reveal the same geological structure. As, for example, the following, which I copy from my note-book of a well upon the Alcorn farm, situated upon the Alleghany River, about three miles above Oil City:

Seventy-five feet of a very soft rock, of the nature of gravel; very soft.

Seventy-five feet of a rock, called by the drillers "soapstone." It is, in reality, an argillaceous shale. It has a somewhat gray colour, and is harder than the preceding rock.

Ten feet of sandstone, everywhere known as "the first sand rock."

Seventy-five feet, another series of shales distinctly argillaceous.

Twenty feet, "second sand rock."

Two hundred feet, argillaceous slates. Layers of rock, alternately soft and hard.

Fifteen feet, "third sand rock."

Eighty feet, argillaceous slates, which the man who was boring described as "shelly," meaning that they were in thin layers of alternately hard and soft rocks.

If we sum up this record we have 550 feet of this formation in a vertical line. The man who was drilling this well said, at the depth of 730 feet, which was the greatest depth he had attained, he had met the same kind of rocks. These rocks belong to the Chemung group, which lies immediately over the Portage in the geological scale. We may, accordingly, safely estimate the thickness of the Chemung group, in Venango county, at 450 feet above the surface, plus 750 below, or at 1200 feet. In this group of rocks, nearly all the oil from Oil Creek, Cherry Run, Patchen's

* From the Journal of the Franklin Institute.

Run, Two-mile Run, Horse Creek, &c., has been found. The Catskill formation does not occur in the oil regions of Pennsylvania.

We have now reached the top of the Devonian system, and find on adding up the above figures that the total depth to which it has been developed in the oil regions is 4000 feet. Concerning all these 4000 feet of rocks, there is nothing which becomes more strongly impressed upon an observer of the geological features of north-western Pennsylvania than the belief that they are sedimentary. That they are, in other words, nothing but the broken and pulverised fragments of other rocks which have been deposited from water; that north-western Pennsylvania was the basin of an ancient sea, which was filled up by the debris of continents.

Ascending in the geological scale, we now come to the carboniferous system. None of the wells which have been sunk along Oil and French Creeks have ever passed through coal. The lowest member of the coal series caps the highest hills near the mouth of Oil Creek, and is, therefore, some 500 feet above the top of any well which has been sunk in that region. The bituminous coal which exists here is of the poorest quality, and occurs in seams of only a foot or eighteen inches in thickness. But this coal has been selling there at sixty cents a bushel, and the cost of feeding the engine has been one of the principal items of expense in sinking a well. To the south, however, of Oil City, in Cranberry township, and along the Allegheny River, the coal veins become thicker. One stretching along the top of a hill, about seven miles below Franklin, is 5 feet in thickness. It is now being worked, and is expected to supply Franklin, Oil City, and the points above, with superior coal. But Franklin is about 500 feet above Pittsburgh, and the general dip of the rocks in a southerly direction is such that in the neighbourhood of the latter town the carboniferous rocks come down to the surface.

In the territory around Pittsburgh, along the Kiskiminetas River, at Slippery Rock, throughout Butler county, at Smith's Ferry, &c., oil is found in the lower coal measures. In this locality they are 800 feet thick. If we trace the Kiskiminetas River nearest its source, oil is found in the lower coal measures, which are 1000 feet thick. Along the Muskingum, Kanawha, and other rivers and creeks about Marietta and Parkersburgh, in Virginia and Ohio, such as the Horse Neck, Bull and Goose Creeks, the upper coal measures contain the petroleum. They are here 700 feet thick. We have now the

Corniferous limestone	50	feet.
Marcellus slate	100	,,
Hamilton group	1000	,,
Genessee slate	300	,,
Portage group	1700	,,
Chemung group	1200	,,
Lower coal measures	800	,,
Middle coal measures	1000	,,
Upper coal measures	700	,,
Total depth of oil-yielding rocks	6850	feet.

In view of these figures let us see what answer should be given to those who are fearful that petroleum is giving out; that nature has manufactured after a stingy fashion the most beautiful means of illumination which she has yet yielded to man; that the refining of petroleum will soon give place to the distillation of bituminous coal; that derricks and tanks will soon cease to vilify the landscape of the beautiful Ohio basin; and that soon, with a terrible crash, oil companies will disappear, and leave nothing but paper behind.

Different wells scattered up and down over 70,000 square miles of land, are now producing oil in profitable quantities. In a large portion of this territory, geology and experience tells us that petroleum exists throughout rocks varying from 50 to 7000 feet in thickness. When petroleum has been exhausted by shallow wells, it may be found in deeper ones, as the famous wells along Oil Creek show us. Here wells were put down at first from 200 to 300 feet, and a heavy lubricating oil was obtained, by pumping, in small quantities. Afterwards, in localities which had been abandoned as unprofitable, wells were sunk to 500 or 600 feet, and flowed one thousand, two thousand, and even in some cases over three thousand barrels daily. Of 340 wells sunk previous to this date between Humboldt Refinery and Rouseville, all that have reached the proper depth have produced oil, and the remainder, 112 in number, will probably experience equal good fortune. These facts alone would justify the statement that henceforth petroleum deserves to be ranked with coal and iron as a solid mining interest.

Such an opinion, moreover, deserves additional weight from a study of the various tracts in Europe, Asia, and South America, where petroleum is collected; and since no statement of this kind has heretofore been published, it will be interesting and valuable to present in this place a world-wide view of petroleum wells. In so doing we must widen to a corresponding degree our ideas of the nature of petroleum. We must recollect that this mineral substance was known many years before the first oil well was sunk near Titusville, and that, under the general name of petroleum, many rock oils should be included, differing greatly in their nature from those mobile fluids which a Philadelphian, who is familiar with the products of Oil Creek alone, is wont to regard as petroleum. We should remember that easily fusible, pitchy bitumens are made up of two ingredients, one of which is a solid body like asphaltum, and the other an oily liquid resembling petroleum, and that wherever such bitumens are found, they are to be regarded as indications of the profitable presence of petroleum. Having made these preliminary statements, we are enabled to speak in a more general manner of foreign oil-bearing rocks, and are not compelled, as we would otherwise be, to regard the few places where petroleum is stated to exist by travellers in precise terms, as the only ones where it is really to be found.

Petroleum found in South America.—In South America bitumen has been discovered in large quantities on the northern shores of New Granada, Peru, and Venezuela, on the banks of the river Magdalena, at Payta or Payti in Columbia, at Coxitambo, near Cuenca, in Peru, and in many other places. Few of these bitumens have been analysed, and we possess, at present, but few facilities for comparing them with European specimens. That of Coxitambo has been investigated, and has been found to be a pure hydrocarbon, consisting of 88·7 per cent. of carbon and 9·7 per cent. of hydrogen. In the travels and researches of Alexander von Humboldt, an account is given of a stream of naptha at the Punta d'Araya, at Cape Cirial, Venezuela. He says that it issues from a mica slate, and remarks, as a singular fact, that petroleum should in this spot issue from a metamorphic rock, while at all others it exudes from secondary rocks. And Boussingault, who has shown in his work on bitumen that all the vast collections of mineral pitch which exist in the northern parts of South America must have a geological position corresponding with bituminous schists found in France, quotes this remark of Humboldt, as the only one which goes to contradict his view of the geological position of the American mineral pitch.

In McCullochs 'Geographical Gazetteer' reference is made to a great mountain of asphaltum upon the north-eastern shores of the great lake of Maracaybo. It sends up, in warm weather, great streams of phosphoric fire, which guide the Spaniards and Indians in their transits over the lake. They have consequently given to this strange lamp of nature the name of the Lantern of Maracaybo. Around the border of the lake, a circumference of about 250 miles, petroleum springs and bitumen abound.

West Indies.—Throughout many of the Islands of the West Indies, and to the north of Venezuela, petroleum springs are found, accompanied generally by deposits of bitumen and vast accumulations of asphaltum. These islands have been upheaved from the sea, during a recent geological epoch, by violent volcanic action. This may account for the fact that petroleum does not, in the West Indian localities, issue from sedimentary rocks as it does in Pennsylvania, but from igneous rocks, or those which have been forced up to the surface of the earth by volcanic agencies. In very many places in Cuba, petroleum flows from cracks in serpentine rocks. Such petroleum springs have been found for two hundred years at Guanabacoa near Havana. And the narratives of the buccaneers tell us that they used to frequent the Bay of Havana, and collect sufficient bitumen lying exposed on the shore at low-water to pay the bottoms of their vessels. In the eastern part of Cuba, springs are found between Holquin and Mayari, and in the other direction in the neighbourhood of Santiago de Cuba. Of the bituminous coal, or as it is called by the natives, chapapote, found in Cuba, more that one-half is composed of volatile fatty matters. An analysis made by Mr. T. G. Clemson, of chapapote from the Casualidad mine, which is situated about 18 miles from Havana, gives only 34·97 per cent. of coke, and the astonishing amount of 63 per cent. of volatile ingredients. It is, of course, an admirable material for the manufacture of gas.

In the great pitch lake of Trinidad, there is a great number of holes and fissures, which have apparently been produced by a rending asunder of the hardened asphaltum by volcanic forces, and a subsequent injection of liquid bitumen. And, in fact, this strange operation of nature's hidden forces may sometimes be seen actually going on in the sea, to the southward of Cape de la Brea. Hidden beneath the waves there seems to be a submarine volcano, which sends up occasionally quantities of petroleum to the surface of the water, attended with a mighty boiling of the deep. And in the same manner the seas in the vicinity of the Cape de Verd Islands are oftentimes covered with petroleum projected from submarine volcanoes. Many years ago an account was published by Dr. Skey, in the English Geological Transactions, of a "petroleum or burning spring," found at St. Andrew's parish in the Island of Barbadoes. He states that it issues from calcareous rocks, and it would appear from his calling it green naptha, and from the fact that it is largely employed by the natives as a substitute for fish-oil in lamps, that the petroleum of Barbadoes is nearly analogous to what we are here familiar with under this name. Mr. Herapath analysed the coal found in Barbadoes, and found that it was equally rich with that mined in Cuba, consisting of 62 per cent. of fatty matters and 37 of coke.

Europe.—In the next place, let us examine the bituminous deposits of Europe. In England, little has been found compared with the extensive developments which have been made in France. Bitumen has been encountered at the Hurlet mines near Paisley, where it incloses crystals of calcareous spar, and at the Odin mines in Derbyshire. It strongly impregnates the peat cut near Ormskirk, Lancashire, and penetrates the limestones of East Lothian in Scotland.

About the year 1840, a mania, M. Dumas tells us, prevailed in France, for putting bitumen to countless industrial appliances. All the provinces of France were explored for asphaltums, bituminous mastics, mineral oils, bituminous schists, sands, sand and lime stones; and some thirty different varieties of asphaltum were exhibited in 1843, by Parisian companies, upon the bourse. In the year 1845, in the department of Ain, Landes, Puy de Dome, Bas Rhine, Haut Rhine, Saône et Loire, there were 16 mines, employing 489 workmen, and yielding an annual revenue of one hundred and twenty-nine thousand dollars. This bore about the same proportion to the amount of money invested, as the yield from the petroleum wells of north-western Pennsylvania and Virginia bears to the capital stock of the companies working them. But asphaltum would not do all that the ignorant newspaper writers of that day said it would, and soon fell in disfavour; companies crashed, and thousands lost heavily. At present, bitumen, with a few exceptions, is restricted in its use to making roads, cisterns, and roofs watertight. The coal basin of Autun, in the department of Saône et Loire, contains largely worked beds of bituminous schists, producing on distillation an oil which is employed for gas-lighting. The bitumen of Seyssel is found in calcareous oolite, from which it is extracted by melting the broken rock in large cauldrons. In warm weather it has a thick pasty consistence and is tenacious, but in cold weather it is solid. In these respects it resembles the bitumens of Magdalena, Payta, and Trinity Island. The bitumen of Bechelbronn is viscous and of a brown colour. It is put to many uses, and especially as a substitute for grease, in lubricating the axles of carriage wheels and the journals of machines. From these and similar applications it has obtained the name of mineral oil, Stein oil, Strasburg grease, &c. Like the bitumen of Coxitambo, it is a pure hydrocarbon, containing 88 per cent. of carbon and 12 of hydrogen.

The bituminous rocks found in France are far surpassed by those of Dalmatia, on the northeastern shore of the Adriatic. The bituminous limestones found here seem to be so charged with liquifiable bitumen that they can be cut as easily as soap, and are formed into bituminous bricks for the sides of houses. When the walls have reached the required height they are set on fire, and burn until all the bitumen is consumed, leaving a white stone. The roof is then put on, and the building completed.

In Italy petroleum is found in many places. That of Amiano in the Duchy of Parma supplies the city of Genoa with light. In the Duchy of Modena petroleum springs are found at Saint Zibio, and in Sicily in the Val di Noto.

At Naples they appear to be connected with volcanic action, and to arise from the bottom of the sea near the southern base of Mount Vesuvius.

Passing over to the Ionian Islands we find large petroleum springs, of which the following account is condensed from the Colonial Statistics of the British Empire, published by R. M. Martin:—The bitumen of Zante is contained in a valley or marshy plain, which is in the form of a segment of a circle, surrounded on three sides by abrupt and rugged ridges of hills. In the marsh within the circle are several wells or pits. The bitumen floats on the surface of the water in these wells. A dark substance continually forces its way from the bottom, and boils up in large globules, which, enlarging till they ascend near the surface, then burst, and liberate a quantity of inflammable gas. Sometimes the globules are transparent and of singular brilliancy, rising to the top and bursting, while a coat of dark bituminous matter in which they are invested is thrown off. This dark substance is the rock-pitch, which, being specifically heavier than water, remains below, covering the sides and part of the bottom of the spring. The brilliant globules disengaged from it are pure naptha or rock-oil, which forms a light oleaginous stratum above, reflecting various beautiful colours. The intervening water is sweet and fit for use. The pitch is collected with large spoons into a pit adjoining the well, and thence thrown into barrels. It is exuded in the greatest quantities in the summer months. About a hundred barrels are annually used for paying the bottoms of ships, and for similar purposes.

Passing by the petroleum springs of Neuchatel, in Switzerland, and at Tagernsee, Bavaria, let us next consider the bitumens of

Asia.—The petroleum wells of southern Asia are of peculiar interest. They were dug thousands of years ago, and when Babylon was in its glory, its skilful artisans made far more extensive use of this facile material than has been found for it at the present day. In a paper communicated by the famous Asiatic explorer, Major Rawlinson, to the Royal Geographical Society of London, he calls attention to the bitumen collected in Kordistan, formerly the great satrapoy of Susiana. He states that even at the present day it is drawn from pits, dug in precisely the same manner as described by Herodotus nearly three thousand years ago. What a treat to the indefatigable illuminator of Herodotus, this striking confirmation and illustration of the text of his favourite author must have been.

The natives all along the Euphrates and Tigris use the petroleum found along the banks of these rivers to pay the bottoms of their vessels, and to burn in lamps instead of oil. And throughout Persia, in the provinces of Farsistan and Kerman, which border upon the eastern shores of the Persian Gulf, in Afghanistan, in the district of Cahut, petroleum springs are found. To the northward, in the Isles of Naptha, which are situated upon the eastern shores of the Caspian Sea, a vast bituminous formation has its origin. It stretches away to the westward for over a hundred miles, and terminates in the hills of the Crimea. It reappears on the western shores of the Caspian, in the peninsula of Abskharon, which forms the eastern end of the Caucasian chain, where it is fully developed as a great deposit of brown coal in a ridge of argillaceous shale. In the neighbourhood are the renowned wells of the fire-worshipping Badkuans, who use petroleum for both light and fuel. These wells are inexhaustible, and refill themselves as fast as emptied. No traveller has given any account of the development, which we would be prone to expect, of petroleum through the Caucasus and Georgia. But in the peninsulas of Kerch and Taman, at the entrance of the Crimean Sea, and near the western extremity of the Circassian range, it is found in considerable quantities. In the great mountain range which skirts the Red Sea, along all the western coast of Arabia, petroleum springs and deposits of bitumen abound in strata wholly composed of oceanic animal matter: countless fossil shells, and rocky crevices, and hollow stones are filled with it; and in the fervid heat of that climate it drops down from the precipitous sides of mountain gorges. And when we follow this great line of volcanic action to the northward, along the valley of Arabia, through the Dead Sea, and up the valley of the Jordan, even to Mount Lebanon, we find scattered along its course deposits of bituminous matter.

Finally, we come to the territories of Assam, and the Birman Empire. In the former, as narrated in the Asiatic researches by Lieut. Wilcox, there are, to the east of Bramahputra, great jungles which are full of the odour of petroleum. Beds of white mud are of frequent occurrence through this region, resorted to greatly by cattle and wild beasts of all kinds, which eagerly devour this substance, probably from its saline properties. Petroleum floats on the edges of these mud springs, but neither it nor the coal which is likewise found in the neighbourhood is used by the natives.

Near the banks of the Irawadi River, between Prome and Ava, many wells of petroleum have been sunk to a depth exceeding 200 feet. They are found along with beds of brown coal, and co-extensive with a tertiary clay formation. In the province of Pegu, around the town of Rainanghong are 180 naptha wells; 340 others are situated four or five miles to the north-east. The gross amount of oil annually obtained from the 520 registered wells is about 100,000 tons, or 420,000 hogsheads, amounting in value to $817,392.

COMMUNICATION BETWEEN DIFFERENT PARTS OF A RAILWAY TRAIN.

(*Continued from p. 250.*)

6. COMMUNICATION by means of the foot-boards I have already referred to at some length. I may here add that where servants of the company are habitually employed to walk along the sides of the carriage they should be provided with a clear space of 2 ft. 4 in. or 2 ft. 6 in. in width for that purpose. The Board of Trade "requirements," which are issued as a guide to engineers in the construction of new lines, contain the following paragraph, which was intended to provide against damage to passengers and servants of the company, particularly in looking out of the carriage windows, as well as to meet other contingencies:—"No standing work above the level of the carriage steps should be nearer to the outer edge of the rail than 3 ft. 6 in. where the carriages are not above 7 ft. 4 in. in width, outside measurement. When the carriages are of a greater width than 7 ft. 4 in. a proportionate increase should be made in the space between any such standing work and the rail. On Irish railways the distance between the outside of the rail and the nearest standing work should be at least 4 feet. On the broad gauge lines in England the distance should not be less than 3 ft. 6 in."

But there has been no means of restricting railway companies as to the width of their carriages after the opening of a line; and the temptations to increase their width on some lines are great. For instance, a first-class carriage of three compartments carrying four passengers in a row, will contain altogether twenty-four passengers, whereas a similar carriage carrying three passengers in a row will only contain eighteen passengers; and the proportional saving of dead weight in the former is considerable, while the cost of construction is not much greater. A still greater economical advantage is obtained in some cases by constructing first-class carriages of four compartments capable of containing thirty-two passengers, and carriages of other classes in similar proportions. A carriage 7 ft. 4 in. wide, projecting 1 ft. 2 in. beyond the rails on each side, allows only 3 ft. 8 in. between the outside of two carriages on different lines of rails, out of the usual 6 feet of intermediate space, and 2 ft. 8 in. out of the 5 feet of intermediate space on some of the older lines; whereas from 4 ft. 8 in. to 5 feet would be required between the carriages, to allow a guard on the side of one train to pass a guard on the side of another train with safety. A carriage 8 feet wide, in like manner, and such a width is by no means uncommon, projecting 1 ft. 6 in. on each side, leaves only 3 feet; and a carriage 9 feet wide, projecting 2 feet on each side, only 2 feet between the two lines of rails.

On the side of the works again, there should, allowing 2 ft. 4 in. from the outside of the carriages to the nearest standing works, be 4 ft. 4 in. for a carriage 9 feet; 3 ft. 10 in. for a carriage 8 feet; and 3 ft. 6 in. for a carriage 7 ft. 4 in. in width; spaces which are not to be obtained on parts of many lines. Communication by the footboards, therefore, with safety to the servants of the companies, would be impracticable without much alteration and restriction for the future, as to the width of the carriages, and without greater alterations of the works than can be contemplated in practice. And the only alternative that remains on the lines of railway in question, which comprehend the principal lines in the kingdom, is that which has already been referred to, of stopping the trains at the nearest place of safety, on an alarm being given by a passenger for a cause not apparent to the servants of the company.

The French commissioners previously referred to, who were specially appointed on the 23rd February, 1861, after the murder of M. Poinsot, in December 1860, on the "Chemin-de-fer de l'Est," to report upon the "Securité des voyageurs dans les trains en marche," state—

"L'un de nous est allé en Belgique étudier spécialement le contrôle de route. Les ingénieurs Belges estiment que ce contrôle occasionne moyennement par an un accident mortel; ce resultat statistique, tel regrettable qu'il soit, est pourtant un bien faible chiffre, si on considére que les contrôleurs passent en quelque sorte tout le temps du voyage sur le marche-pied."

The number of (English) miles open for traffic in Belgium in 1860 was 1288; and the number of miles now open in this country are 12,799. Supposing a proportionate number to be killed in this country, we should sacrifice ten lives annually, after having gone to enormous expense in alterations of works and rolling stock, besides wounding a much greater number of servants of companies, in attempting to carry out this system of communication. Such a result would hardly be satisfactory. The commissioners proceed to state:—

"Le contrôle de route, il faut le reconnaître, sera, quoi qu'on fasse, toujours accompagné d'un certain péril. Le prescrire d'une manière absolue sur toutes les lignes et en tous les points, ce serait pour l'administration assumer la responsabilité de graves accidents et jouer un rôle fâcheux auprès des agents des compagnies. Indépendamment de cette considération, nous avons vu que, dans un grand nombre d'ouvrages, il faudrait élarger l'accotement, en rétrécissant l'entrevoie, mais que ce rétrécissement ne pouvait dépasser certaines limites. Nous avons énuméré ces ouvrages (3° dossier). Toutefois, notre énumération peut n'être pas complète; certaines circonstances particulières ont pu même échapper aux ingénieures de contrôle. Il est donc bien évident qu'à cet égard les compagnies doivent dans le principe, rester juges des modifications possibles a l'entrevoie."

They considered that a man "circulant avec precaution sur le marchepied pourra passer partout ou passe une portiere ouverte," or in a space of 2 feet. The carriages in France vary in width from 8 ft. 8 in. to 8 ft. 6 in.; the intermediate space between the rails from 6 ft. 6 in. to 5 ft. 10 in.; and the distance between the rails and the works, from something less in many cases, to 4 ft. 2½ in. in the majority of cases. The commissioners came to the following conclusions:—

"1. Le contrôle de route est partout impossible du côte de l'entrevoie.

2. Le contrôle de route n'est possible sur l'accotement qu' avec une distance de 1 m. 30 (4 ft. 3 in.) entre l'axe du rail extérieur et les parois d'ouvrages et objets de toute nature placés sur le flanc de la voie. Cette distance de 1 m. 30 peut d'ailleurs n'être considérée qu' á 1 m. 20 au dessus du rail (hauteur a l'arête inférieure, d'une portière ouvert); mais elle doit en revanche régner encore à 2 m. 70 (hauteur de l'arête supérieure de la dite portière) au dessus de ce même rail."

But they recommend that—

"Les compagnies devrait organiser sur toutes les voitures composant les trains du voyageurs un système de marchepieds et de mains courantes horizontales, qui permette, soit aux agents mêmes du train, soit à des contrôleurs spéciaux, de parcourir toute la longueur du convoi du côté des accotements du chemin. Les mains courantes pourront, être interrompus devant les portiéres; mais elles dèborderont, ainsi que le marchepieds, les deux extrémités de la voiture a 25 centimètres au moins de largeur."

7. *Glass between compartments.*—This system has already been adopted experimentally on several lines in this country. It would be a partial remedy for the evils complained of, as regards outrage, but no protection against accident. It would naturally be least agreeable to passengers on long journeys, where protection is most called for; and it would afford no means in the general way of attracting the attention of the servants of the company. Any curtains provided for covering the glass would tend to prevent the glass from being useful in case of necessity. The French commissioners, however, before referred to, reported as follows:—

"La glace dormante placée à la partie supérieure des cloisons offre, sur une moindre échelle, quelques uns des avantages de la communication entre compartiments. Elle peut dans certains cas, être d'un utile secours aux voyageurs, inspirer une crainte salutaire aux mal intentionnés et constituer, en tout cas, un épouvantail matérial ou moral. Elle ne porte aucune atteinte ni á la commodité, ni à l'indépendence des voyageurs, qui seront toujours à même d'en masquer l'ouverture, s'ils le jugent à propos. Elle peut d'ailleurs, être faite avec une tres faible dépense. Elle ne laisse en outre passer, ni les paroles des voyageurs, ni les courants d'air, ni la fumée de tabac. En conséquence, nous pensons que, par l'application de l'article 12 de l'ordonnance du 15 Novembre, 1846, on peut donner la securité publique, une satisfaction aussi peu dispendieuse, et inviter les compagnies à installer immédiatement, dans toutes les cloisons, une ou deux glaces dormentes, ayant un minimum 0m. 10 de haut, sur 0m. 25 de large, placées immédiatement, au dessous des filets à menus baggages et pouvant être recouvertes de chaque côté par un piéce d'etoff mobile."

8. *Cords though the trains connected with whistles or bells on the engine or tenders.*—This system has already been referred to at

length, as being in extensive use both here and elsewhere; and as having been found to fail in very long trains in its simple form, though such failures might no doubt be avoided by more perfect arrangements. It is hardly fitted for further complication, connected with interior and exterior signals for the different compartments of each carriage, though some ingenious methods of accomplishing this object have been proposed.

9. *A travelling porter*, or look-out man, has also been referred to as useless in fogs, or in darkness, without extra illumination, and it may be added that the expense of an extra servant with every train, to do little or nothing else but keep a look-out of partial or questionable utility, would be very considerable.

10. *Electrical* (*voltaic*) *apparatus* would appear upon the whole to be the best adapted for ensuring perfect intercommunication at all times between all parts of a train, though they have the disadvantage of being worked by batteries which require to be examined, say once a month, and renewed, say every six months.

The French Commission of 1861 report on the subject, as follows:—

"Une communication électrique pourrait seule résoudre le problème (voir No. 31, lettre du Sieur Fragnaux). Mais une réflexion qui n'a pas été assez faite, et qui domine évidemment toute la question, c'est qu'avant de donner au voyageur le moyen d'appeler à lui les agents du train, il faut d'abord donner á ces agents le moyen de se rendre aupres du voyageur, car on ne peut raisonnablement admettre qu'on arrête le train au premier signal émanant d'un compartiment. Il nous semble donc tout à fait premature de mettre les voyageurs en relation avec les agents du convoi, tant qu'on n'aura pas resolu la quettion du contrôle de route."

I have already referred to a remark which was made in regard to such apparatus by the Clearing-house committee of 1853, and I append a list and brief description of the different patents which have been taken out at different times for the use of such apparatus.

The most promising apparatus that I have yet seen is of this description, and has been fitted up on the London and South-Western Railway, under the direct superintendence of Mr. Preece, the telegraph superintendent of that railway, a patent having been obtained for it by Messrs. Preece and Bedborough. Believing that it was likely to prove efficient, I have myself taken pains in suggesting modifications as to some of its parts; and I think that it merits in its present state a detailed notice.

The required communication is effected by a complete voltaic circuit throughout the train. A passenger by breaking the glass face of a small box in any compartment of any carraige, causes a semaphore arm to drop on each side of the carriage, and bells to ring in every guard's van and on the engine (or tender) all at the same moment. A guard, by pressing a small button in any break-van, rings the engine-driver's bell, and the bells of any other guards there may be in the train. The engine-driver can ring in like manner the bells of all the guards, and is thus provided with a signal to be used in addition to his steam whistle. The bells of the engine-driver and guards are all rung on the fracture of any of the couplings in the train. No lamps are provided for night signals, it being thought sufficient that the guard should, after the train is stopped in obedience to the signal of the passenger, be guided by the semaphore arms only to the proper compartment.

The instrument to be acted upon by the passenger is on the same principle as the child's toy—the jack-in-the-box. As soon as either of the glasses which form its faces is broken (by a blow from a book, parasol, walking-stick, or other article in common use), a small piston thus released is urged forward by a spiral spring; catches are lifted from pins provided on the semaphore arms at the sides of the carriage; these semaphore arms fall by the force of gravity from a nearly vertical to a horizontal position; and the earth connection being formed on both sides of the carriage, the voltaic circuit is completed in both directions. Each box has two glass faces, one projecting into each of the contiguous compartments in each carriage. It is as yet a question whether the spring in the box ought to be placed longitudinally, or transversely between the semaphore arms.

The semaphore arms are constructed of iron, and are sufficiently heavy to fall with certainty by their own weight, as soon as they are released in the manner above described. They rub in falling against three metal springs provided for the purpose on each side of them; and they strike on a copper wire, so that four surfaces are presented which can hardly fail in combination to ensure voltaic contact.

The couplings between the carriages have already been used successfully on the French railway, the "Chemin-de-fer du Nord." The coupling-hook is of gun-metal, and is kept from contact with a knob of similar metal above it, as long as the eye is upon it, but as soon as the carriages become detached, the eye is pulled off the hook; the latter is forced up by the action of a self-contained spring against the knob; and the circuit being thus completed, the bells are rung throughout the train.

In order to ensure a more perfect connection, and to provide for the carriages being used in either direction, two wires are placed under, and two couplings are affixed at each end of each carriage.

The bells in the guards' vans and on the engine are trembling bells, of the ordinary description, ringing incessantly as long as the current is maintained; except that they are prevented from ringing when the circuit is incomplete, from the mere oscillation of the train, by an ingenious device. A stop-bar, which is in fact the armature of a second magnet, falls and interposes between the striker and the gong whenever the circuit is broken, and is lifted out of the way when the current is re-established. This bell has also, I believe, been used in France.

The only part of this apparatus which appears to be liable to fail in practice is the glass face of the jack-in-the-box. It is a question whether the enormous number of glasses that would be required could be so nicely adjusted as not on the one hand to be fractured too easily from the jolting of the carriages, or on the other hand to require too great a blow from a passenger. It is not desirable that they should be liable to fracture by a slight accidental blow, or without serious intention or real cause of alarm. And there is no reason why a small hammer or mallet should not be suspended near each box, with which a stout glass or porcelain face might be easily broken. But, indeed, the jack-in-the-box principle is by no means essential or necessary to the remainder of the apparatus, which may quite as easily be set in action by a button or handle of any description, either covered by glass, or so enclosed in glass as to be incapable of action without the fracture of the glass. The first cost of this system would be very considérable, though small when compared with the capital of the respective companies.

It is estimated that the fitting up of every engine and van would cost £8 5*s*., of every carriage £3 10*s*., and of each carriage-truck, horse-box, &c., £2. Assuming that the fitting up of engines, carriages, vans, and all vehicles employed in passenger trains, could be efficiently completed at the rate of £8 for every passenger carriage, then the total cost (based on the returns of rolling stock up to the end of 1863) would be, on the following lines:—

	£.			£.
London & North Western	16,464,	as against a total capital of		43,692,885
Great Western	12,490	,,	,,	42,562,277
(allowing £10 per carriage.)				
North Eastern	8,604	,,	,,	35,043,303
Great Eastern	7,912	,,	,,	24,159,058
London & South Western	7,672	,,	,,	13,846,127
Midland	7,256	,,	,,	27,448,638
Great Northern	5,240	,,	,,	13,646,276

Calculating at £10 per mile on an average for all lines in England, Scotland, and Ireland, the total cost of its adoption would be about £127,990.

The cost of maintenance would not be very great, though no doubt the necessity for keeping so many extra appliances in working order would be a serious objection and disadvantage to the railway companies; and if the general condition of carriage lamps be taken as a test, the difficulties in such a case would appear to be great.

A man would be required at each important junction and at each terminal station, to examine, test, attend to, and renew the apparatus as required; and an inspector on long lines of railway over every three or four men. The expense of these men and of renewals would vary much on different lines, but may be roughly estimated at 10 per cent. on the first cost above given. It would thus be on the same lines—

	£.			£.
London & North Western	1646,	as against working expenditure for 1863		2,413,410
Great Western	1249	,,	,,	1,672,166
North Eastern	864	,,	,,	1,330,198
Midland	725	,,	,,	1,017,198
London & South Western	767	,,	,,	678,104
Great Eastern	791	,,	,,	796,351
Great Northern ...	524	,,	,,	802,987

There can, I think, be no doubt of the possibility by some such method as the above, as well as by other methods, of providing a means of intercommunication in trains in a more or less perfect manner according to the expense incurred; and it only remains to make one or two remarks in conclusion upon the very important question, how far it may be desirable to place such a communication in the hands of the public.

It is impossible to consider this part of the subject without drawing a distinction between those long journeys in which it is more required, and that railway omnibus traffic in which it would be of minor utility.

It seems preposterous on the one hand to deny to a passenger who is shut into a compartment for an unbroken journey of from one to two hours any opportunity of calling attention, and if necessary of stopping the train, in the event of fire, of serious accident, of gross outrage, or of alarming illness. On the other hand, those passengers who cut the carriage linings, write with diamonds upon the carriage windows, and break the lamp glasses, and this more commonly on short journeys, cannot be expected altogether to abstain from interference with any signals which may be provided for their protection. Unless the servants of the company were instructed to stop each train after an alarm had been given (upon seeing no exterior cause for it) under the protection of the first fixed signals that they reached, there would be comparatively little use in providing a means of communication to them from the passengers, as a protection against outrage; and if the trains are to be stopped whenever a passenger makes a signal, it is necessary that some provision should be made by the legislature for the punishment of those who cause the stoppage of trains without just cause, as well in the interest of the travelling public as in that of the railway companies. There would be a further difficulty, which cannot be overlooked, in dealing with persons of either sex who might imagine or exaggerate dangers, which either did not exist or did not render necessary the stoppage of a train.

It would hardly be possible, politic, or proper, to inflict punishment upon such persons, acting from an honest feeling of real alarm; but a better remedy for or preventive against such an abuse of the system is probably to be found in the use of such an instrument in the carriages, whatever its form, as would be unlikely to be set in action unless in case of urgent necessity. Any uncovered handle, or tassel, or knob, placed within too easy reach, would be liable to be trifled with and to be set in action by a child, or a nervous passenger, almost or quite unintentionally; whereas a glass not too slight, used as a screen or cover, or as in the method above described, would only be broken under the pressure of considerable alarm. The key of the door of each compartment has in some of the French railway carriages been placed within reach and protected in this manner.

I have not desired, in preparing this report, so much to offer any direct expression of my own opinion as to what, if any, means of communication between passengers and guards should be provided, as to place the whole question fairly before their lordships, its history, its difficulties, the modes in which they may be met, the dangers to be encountered, the advantages to be obtained, by the different methods proposed; and I hope that some assistance may thus be rendered to the meeting of general managers at the Railway Clearing-house, as well as to those noblemen and gentlemen in both Houses of Parliament by whom the decision as to what will be most desirable on the part of the railway companies, and in the interests of the public, must ultimately be pronounced.

DUBLIN WATERWORKS.*

By P. Neville.

The supply of water to the city of Dublin was for several centuries entirely obtained from the river Dodder, across which a weir has been constructed near Templeogue at about five miles distance from Dublin, and whence the water was and is still conveyed into Dublin by an open conduit called the City Watercourse. In 1775 the water supplied from this source was found so bad and insufficient that the corporation arranged for obtaining what was then considered an ample supply of water from the Grand Canal; and again in 1806, the quantity having become insufficient, a better supply was procured from the Grand Canal, and also from the Royal Canal, which was measured by overfalls of a certain length. This last arrangement was made to extend over a term of sixty years, and under it Dublin has been supplied up to the present date. The Royal Canal supplies water to the north side of the city, and the Grand Canal and City Water-course to the south side, the water for the former being received in the city basin at Blessington-street, and for the latter into the James's-street and Portobello basins. The level of the water in the north side basin is 78 feet, and in the south basin 76 feet, above Ordnance datum, which is the level of low-water of a twelve-feet tide. The surface levels of the lowest parts of the city along the quays range from 20 feet to 28 feet above this datum, and the head of water in this part of the city is, therefore, only about 50 feet, while over the average of the city it is not more than 25 feet, and some parts are at too high a level to be supplied at all. The water obtained from the Dodder is of a soft quality, and would be very good for domestic use were it not for the pollutions received from paper and other mills which have been allowed to be erected from time to time along the course of the river. The water of the canals is very hard, having a hardness of 15 deg. to 16 deg. by Clarke's test, and it is liable to great pollution. For many years the want of a really good supply of soft water, and at high pressure, for the city and suburban districts was strongly felt, and various plans were proposed for obtaining a new or improved supply. In 1857 it was proposed to obtain a supply from the canals from a higher level where their water was more pure, and it was afterwards proposed to obtain water from the Liffey at about twenty miles above Dublin; subsequently, in 1860 the whole question of the water supply to Dublin was referred to a royal commissioner, Mr. Hawkshaw, who recommended the obtaining a supply of water from the river Vartry. An Act was obtained in 1861 for the purpose of carrying this into effect, and the work was commenced in November 1862, the amount of the contract for the whole being £274,000. Finally, in 1860, it was decided that the best source from which an improved supply could be obtained, was the river Vartry, and for this purpose the Dublin Corporation Waterworks Act was passed in 1861, and the first stone of the new works was laid at Stillorgan in 1862. The river Vartry rises at the southern base of the great Sugar Loaf Mountain in the county of Wicklow, and flows in a southerly direction through a very thinly populated country, reaching the Devil's Glen at a distance of about ten miles from its source. After passing over the fall, it continues through the glen, and by Ashford and Newrath bridges to the broad lough, from which it flows into the sea at Wicklow. The water of the Vartry is collected entirely from a clay slate district, and is peculiarly soft and pure, and during the greater part of the year quite free from all colour. It is almost identical in analysis with the Loch Katrine water, which now supplies Glasgow. Rain gauges have been set up in different positions, and at different elevations within the drainage area of the catchwater basin, which have been accurately observed for more than four years, and they have registered the following as the average annual receipt over the whole area:—

	Inches.
1861	60·87
1862	60·48
1863	44·85
1864	48·39

This is a much larger rainfall than it was originally calculated that the district would yield, and leaves no doubt as to the sufficiency of supply; and the whole of the water from the catchment is available for the waterworks purposes, as all mill rights, &c. along the course of the river have been bought up, and no compensation water has to be given off.

The place selected for the formation of the storage reservoir is at Roundwood, about 7½ miles below the source of the river; and at the point where the great embankment for the reservoir has been constructed. The bed of the river at this point is 632 feet above Ordnance datum, or 520 feet above the highest part of Dublin. The drainage area above this point is 13,992 acres, or 22 square miles, and the area of the reservoir will be 409 acres. When full, the level of the water will be 692 feet above the datum, and the reservoir will hold about 2,400,000,000 gallons of water, or 200 days' supply for the city and suburban districts, taking the daily quantity required at 12,000,000 gallons; but this is much in excess of what it is expected will actually be required for many years, as the present population to be

* Read to the Institution of Mechanical Engineers.

supplied is only about 340,000. The quantity calculated for would supply a population of 400,000 with 25 gallons per head per day, and leave a surplus of 2,000,000 gallons per day for manufacturing and other purposes.

The main embankment of the Roundwood reservoir is 66 feet high in the deepest part, and the greatest depth of water in the reservoir 60 feet. The embankment is 2000 feet long on the top, and will have a public road 24 feet wide carried over it. The entire breadth of bank at top is 28 feet, and at base, in the deepest part, 380 feet. The outer slope 2½ to 1, and the inner 3 to 1, and the total quantity of earthwork in the embankment is 320,000 cubic yards. The puddle wall is 6 feet wide at top and about 18 feet wide at bottom, on the level of the surface of the old river bank, and throughout its entire length the puddle wall is carried down to the solid rock. The by-wash, or waste weir, is 300 feet long. A tunnel for the outlet from the reservoir is formed under the eastern end of the embankment by excavating an open cutting into the rock, and then arching it over with a semicircular arch of ashlar stone 4 feet thick; it is 14 feet high by 14 feet wide in the broadest part. Near the centre of this tunnel is a brick plugging 20 feet thick, carefully toothed into wedge-shaped recesses in the solid rock. Through this plugging are laid two cast-iron pipes of 48-inch and 33-inch diameter, the larger of which is intended chiefly as a sluice for lowering the water level in the reservoir quickly, and it is continued into the tail of the by-wash near where the latter joins the old river course. The 33-inch pipe is for conveying the water into the circular distributing basin, from which it passes by conduits to the filter beds, and thence into the pure water tanks. In the valve chamber at the outer end of the embankment tunnel a very complete set of stop valves will be placed, for enabling both the 48-inch and 33-inch pipes to be worked, as may be required. At the inner end of the embankment tunnel is built a water tower, into the bottom of which the 33-inch pipe is carried; and in the sides of the tower are inlet openings with valves fixed on the inside, for enabling the water to be drawn from the reservoir at different levels, in order that it may be drawn off in the best state for use.

The filter beds and pure water tanks cover about 6 acres. There are seven filter beds, each 205 feet long by 110 feet wide, and any six of these working at the same time will be sufficient to filter the required quantity of water, so that one can always be spared for the purpose of cleansing and washing the sand, for repairs, &c. The filtering material employed will be sand, gravel, and broken stone. The two pure water tanks which receive the water from the filters hold 2,730,000 gallons of water each, and are placed so that four of the filters are on one side of them and three on the other, the remaining space on the latter side being occupied by a sand cleansing machine, and store for the sand. From these tanks the water will be carried for a distance of about 700 yards in a cast-iron pipe 42 inches diameter, laid with a fall of 6 feet per mile until it reaches the tunnel, into which it is carried for a length of 120 yards, so as to get to the solid rock.

The tunnel will be 4367 yards long, or nearly 2½ miles, the entire length being through very hard Cambrian rock, full of quartz veins. Twenty-one shafts have been sunk along the course of the tunnel, from which the miners work right and left; and up to the present date the headings from five of the shafts have met, and 3160 yards, or 1¾ miles, have now been tunnelled. The tunnel is 6 feet high and 4 feet wide, and has a fall of 4 feet per mile throughout. This work has turned out much more difficult and tedious than was anticipated, chiefly owing to the hardness of the rock, and the great quantity of water met in the shafts and headings, which requires very large pumping power, and it is calculated that the tunnel cannot now be completed before the latter end of next year.

At the lower or Dublin end of the tunnel there will be a relieving tank and measuring weir, where the water passed down for the supply of the city will be gauged daily. From this tank, in which the surface of the water will be 606 feet above the Ordnance datum, a 33-inch main conveys the water to the distributing reservoirs of Stillorgan. A self-acting stop valve at its junction with the tank prevents flooding, in the event of a pipe bursting. The average fall in gradient at the main is 20 feet per mile, and it passes the village of Newtownmountkennedy, and then along the coach road through the Glen of the Downs to the Kilmurray relieving tank, which is 7 miles from the lower end of the tunnel. This tank is circular, excavated out of a gravel hill, and lined with puddle, covered with pitching. The end of the main delivery into the tank has a 33-inch double-acting stop valve, and there is a self-acting valve on the mouth of the main leaving the tank. The surface level of the water in this tank is 473,000 feet above ordance datum, and the main is then brought down again to the road, and continued 3 miles to the Kilcrony tank, situated on the top of the southern bank, and commanding a remarkably fine and extensive view. Owing to the loose character of the quartz rock in which this tank is excavated, it has to be lined with puddle. The water head is 214 feet above the datum, and the tank is provided with inlet and outlet 33-inch valves, similar to the preceding. The main is then carried down under the Dargle river, afterwards under the Cookstrevan river, and to the Rathmichael relieving tank at 3½ miles' distance, which is excavated in the rock, and happens to be situated exactly on the junction of the granite with the clay slate, so that one side of the tank is in granite and the other in slate. This is a square tank and puddled, and the level of the water in it is 341 feet above the datum. Here also there will be a double-action stop valve and a self-acting valve, as described for other tanks. The main is then continued for nearly 4 miles, partly along the Wicklow Railway, having a self-acting valve and stop valve inserted in this length, and it terminates at the two distributing reservoirs at Stillorgan, making a total distance of 17½ miles from the lower end of the tunnel. The water area of these reservoirs is 18 acres, and their average depth about 20 feet, so that these two will contain about 90,000,000 gallons of water. The surface level of the water in the upper reservoir is 274 feet, and in the lower 271 feet, above the datum, and the latter is, therefore, the working pressure for the supply of Dublin, the distance being 4¾ miles from the city boundary, making a total distance from Roundwood reservoir of 25 miles. The 33-inch main is laid into each reservoir, and the stop valves are so placed that either reservoir can be worked at pleasure; the two reservoirs are also connected together by a pipe laid through the dividing embankment.

At the lower reservoir is constructed the valve house and screen chamber, into which mains from each reservoir are laid, together with one in direct continuation from the Vartry main, and by the system of valves placed in this chamber the water can be drawn from either of the reservoirs or direct from the Vartry main. In the latter case it is not exposed in the reservoirs at all, which, in warm weather, it is calculated will be a great advantage, as the water will thereby be delivered cold and pure. At the same time there is the security of having always about ten days' supply of water in the reservoirs in case of any accident to the main pipe, thus obtaining ample time for any repair. The screen chamber will contain a set of copper wire screens, through which the water is strained before entering the delivery mains, so as to remove the possibility of any small substance being carried into the mains. These screens will be cleansed periodically by a hose and jet, and the arrangement of valves are such as to allow of this being done at any time without interfering with the regulating of the supply. A double line of twenty-seven mains are laid out of the screen chamber with self acting valves, extending 4¾ miles to the city boundary. The double line has been laid with the view of preventing the possibility of any stoppage in the supply by the bursting of a main or the necessity for any occasional repair; and connections are made between the two mains at three points, with groups of stop valves, to afford the means of turning the water from one main into the other as occasion may require. The valves have been placed on all summits, and scouring valves in all hollows.

LIMES, CEMENTS, MORTARS, AND CONCRETES.*

By Chas. H. Haswell.

The calcination of marble or any pure limestone produces lime (quicklime.) Lime, from its great affinity for moisture and carbonic acid, requires to be preserved from these deteriorating agents by being packed in close vessels.

Limestones.—The pure limestones burn to a white lime, and give the richest limes.

The finest calcareous minerals are the rhombohedral prisms of calcareous spar, the transparent double-reflecting Iceland spar, and white or statuary marble.

* Collected from the observations and experiments of Generals Gilmore and Totten, U.S.A., and MM. Vicat, Chatoney, Rivot, and Dupont. (From the Journal of the Franklin Institute.)

In order that lime when brought to the condition of a paste for use as a binding medium shall afterwards harden to solidity, it is necessary that other substances exist in a state of intermixture with it; and these substances are found to be silica, alumina, magnesia, iron, manganese, &c.

The striking and characteristic property of hardening under water, or when excluded from the air, conferred upon a paste of lime by these foreign substances, when their aggregate amount exceeds one-tenth of the whole, furnishes the basis for a general arrangement of all natural or artificial products suitable for mortars, into five distinct classes, as follows:—

1. The common or fat limes.
2. The poor or meagre limes.
3. The hydraulic limes.
4. The hydraulic cements.
5. The natural puzzuolanas, including puzzuolana properly so called, trass or terras, the arènes, ochreous earths, schists, grauwacké, and basaltic sands, and a variety of similar substances.

Rich limes are dissolved fully in water frequently renewed, and they remain a long time without hardening; they also increase greatly in volume, from 2 to 3·5 times their original bulks, and will not harden without the action of the air. They are rendered hydraulic by the admixture of puzzuolana or trass.

Rich, fat, or common limes usually contain less than 10 per cent. of impurities.

Hydraulic limestones are those which contain iron and clay, so as to enable them to produce cements which become solid when under water.

The pastes of fat limes shrink, in hardening, to such a degree that they cannot be used as mortar without a large dose of sand.

Poor limes have all the defects of rich limes, and increase but slightly in bulk.

The poorer limes are invariably the basis of the most rapidly setting and most durable cements and mortars, and they are also the only limes which have the property, when in combination with silica, &c., of indurating under water, and are, therefore, applicable for the admixture of hydraulic cements or mortars. They generally contain silica (in the shape of sands), alumina, magnesia, oxide of iron, oxide of manganese, and in most cases traces of the alkalies in relative proportions, which vary very considerably in different localities. Their aggregate amount is seldom less than ·10 or greater than ·25, though in some varieties it reaches as high as ·35, and even, though rarely, ·39 of the whole. In slaking, they proceed sluggishly as compared with the rich limes, and seldom produce a homogeneous and impalpable powder. They exhibit a more moderate elevation of temperature in slaking, and are accompanied by a much smaller increase of volume than rich limes. Like the latter, they dissolve in water frequently renewed, though more sparingly, owing to the presence of a larger amount of impurities, and like them, they will not harden if placed in a state of paste under water or in wet soil, or if excluded from contact with the atmosphere, or carbonic acid gas. They should be employed for mortar only when it is impossible to procure common or hydraulic lime, or cement, in which case it is recommended, if practicable, to reduce them to powder by grinding.

Lime absorbs in slaking a mean of 2·5 times its volume and 2·25 times its weight of water.

Hydraulic limes are those which readily harden under water. The most valuable, or "eminently hydraulic," set from the second to the fourth day after immersion; at the end of a month they become hard and insoluble, and at the end of six months they are capable of being worked like the hard natural limestones. They absorb less water than the pure limes, and only increase in bulk from 1·75 to 2·5 times their original volume.

The inferior grades, or "moderately hydraulic," require a longer period, say from fifteen to twenty days' immersion, and continue to harden for a period of six months.

The property of hardening under water or when excluded from air, conferred upon a paste of lime, is effected by the presence of foreign substances, as silicum, alumina, iron, &c., when their aggregate presence amounts to one-tenth of the whole.

The resistance of hydraulic lime increases if the sand is mixed in the proportion of 50 to 180 per centum of the part in volume; from thence it decreases.

As a general rule these limes undergo, in slaking, an increase of volume inversely proportional to their hydraulicity and quickness.

Slaked lime is a hydrate of lime.

M. Vicat declares that lime is rendered hydraulic by the admixture of a proportion of from 33 to 40 per centum of clay and silica, and that a lime is obtained which does not slake, and which quickly sets under water.

Artificial hydraulic limes do not attain, even under favourable circumstances, the same degree of hardness and power of resistance to compression as the natural limes of the same class.

The close-grained and densest limestones furnish the best limes.

Hydraulic limes lose or depreciate in value by exposure to the air.

Arènes is a species of ochreous sand claimed to be of fossil origin. It is found in France. On account of the large proportion of clay it contains, sometimes as great as seven-tenths, it can be made into a paste with water without any addition of lime, and hence it is sometimes used in that state for walls constructed *en pisé*, as well as for mortar. Mixed with rich lime it gives excellent mortar, which attains great hardness under water and possesses great hydraulic energy.

Puzzuolana is of volcanic origin. It comprises trass or terras, the arènes, some of the ochreous earths, and the sand of certain grauwackés, pramuntes, granites, schists, and basalts; their principal elements are silica and alumina, the former preponderating. None contain more than 10 per cent. of lime. When finely pulverised without previous calcination, and combined with the paste of fat lime, in proportions suitable to supply its deficiency in that element, it possesses hydraulic energy to a valuable degree. It is used in combination with rich lime, and it may be made by slightly calcining clay, and driving off the water of combination at a temperature of 1200°.

Trass or terras is a blue-black trap, is also of volcanic origin. It is obtained from pits of extinct volcanoes, and has nearly all the distinguishing elements of puzzuolana, resembling it in composition and in the requirements of its manipulation, requiring to be pulverised and combined with rich lime, to render it fit for use and to develop any of its hydraulic properties. (For an analysis of them, see Burnell on Limes, Cements, Mortars, &c.)

Brick or tile dust combined with rich lime possesses hydraulic energy.

General Gilmore* designates the varieties of hydraulic limes as follows: if, after being slaked they harden under water in periods varying from fifteen to twenty days after immersion, slightly hydraulic; if from six to eight days, hydraulic; if from one to four days, eminently hydraulic.

The aggregate of silica, alumina, magnesia, oxide of iron, &c., contained in these limes seldom exceeds ·35 of the whole. The proportion in the first class varying from ·10 to ·20 of the whole, in the second class from ·17 to ·24, and in the latter class from ·20 to ·35.

Pulverised silica burned with rich lime produces hydraulic lime of excellent quality. In experiments by MM. Chatoney and Rivot, this lime hardened under water in from three to four days, and acquired in twenty-two months a hardness superior to Portland cement. The weight of the powdered lime never exceeded four times, and never less than one-half, that of the powdered silica.

Hydraulic limes in their composition, and in their value for application to the purposes of construction, and in their geological position, occupy an intermediate place between the common or fat limes and the hydraulic cements. They are found in the United States, in numerous and extensive deposits. Hydraulic limes are injured by air slaking, in a ratio varying directly with their hydraulicity, and they deteriorate by age. For foundations in a damp soil or exposure, hydraulic limes must be exclusively employed.

Cements.

Hydraulic cements contain a larger proportion of silica, alumina, magnesia, &c., than any of the preceding varieties of lime; they do not slake after calcination, and they are superior to the very best of hydraulic limes, as some of them set under water at a moderate temperature (65°) in from three to four minutes; others require as many hours. They do not shrink in hardening, and make an excellent mortar without any admixture of sand.

Roman cement is made from a lime of a peculiar character found in England and France, derived from argillo-calcareous kidney-shaped stones, termed "Septaria," and when mixed thick it solidifies in a few minutes either in air or water; hence, for

* See his Treatises on Limes, Hydraulic Cements, and Mortars, in Papers on Practical Engineering, Engineers' Department, U.S.A.

some purposes, it is of great utility, and for others its use is impracticable.

The manufactured article takes its name from the locality of the store, as "Boulogne" or "Sheppy."

Rosendale cement, from the township of Rosendale, N.Y., is derived from the water limestone of the Helderburg group, Ulster county, New York.

Portland cement is made in England and France from an argillo-calcareous deposit, which is burned and ground up for cement in its natural state, without the addition of lime. It requires less water than the Roman cement. It sets slowly, and can be remixed with additional water after an interval of twelve or even twenty-four hours from its first mixture.

The property of setting slow may be an obstacle to the use of some designations of this cement, as the Boulogne, when required for localities having to contend against immediate causes of destruction, as in sea constructions having to be executed under water and between tides. On the other hand, a quick-setting cement is always difficult of use; it requires special workmen and an active supervision. A slow-setting cement, however, like the natural Portland, possesses the advantage of being managed by ordinary workmen, and it can be remixed with additional water after twelve or even twenty-four hours.

Artificial cement is made by a combination of slaked lime with unburnt clay in suitable proportions, burning the mixture in a kiln or furnace and then grinding it, or by substituting for the lime a carbonate of a lime that can be pulverised without burning, or by using artificial puzzuolana, or by adding silica in a soluble form to a paste of common lime.

Artificial puzzuolana is made by subjecting clay to a slight calcination.—(Pambour.)

Salt water has a tendency to decompose cements of all kinds.

Mortars.

Lime or cement paste is the cementing substance in mortar, and its proportion should be determined by the rule, that the volume of the cementing substance should be somewhat in excess of the volume of voids or spaces in the sand or coarse material to be united. The excess being added to meet imperfect manipulation of the mass.

Hydraulic mortar, if re-pulverised and formed into a paste after having once set, immediately loses a great portion of its hydraulicity, and descends to the level of the moderate hydraulic limes. A great destruction of the hydraulic principle therefore results from any disturbance of the molecular arrangement of the mortar, after crystallization has commenced. This is what occurs with the intermediate limes, which take initial set promptly and firmly, but which are subsequently thrown down by the slaking of the impure caustic lime which they contain.

All mortars are much improved by being worked or manipulated, and as rich limes gain somewhat by exposure to the air, it is advisable to work mortar in large quantities, and then render it fit for use by a second manipulation.

White lime will take a larger proportion of sand than brown lime.

The use of salt water in the composition of mortar injures the adhesion of it.

Mortar.—When a small quantity of water is mixed with slaked lime, a stiff paste is made, which upon becoming dry or hard, has but very little tenacity, but by being mixed with sand or like substances, it acquires the properties of a cement or mortar.

The proportion of sand that can be incorporated with mortar depends partly upon the degree of fineness of the sand itself, and partly upon the character of the lime. For the rich limes, the resistance is increased if the sand be in proportions varying from 50 to 240 per centum of the paste in volume; beyond this proportion the resistance decreases.

Stone mortar.—325 lb. cement, 120 lb. lime, and 14·67 cubic feet of sand.

Brick mortar.—325 lb. cement, 120 lb. lime, and 12 cubic feet of sand.

Brown mortar.—Lime one part, sand two, and a small quantity of hair.

Lime and sand, and cement and sand, lessen about one-third in volume when mixed together.

*Analyses of Hydraulic Limes, Cements, Trass, and Puzzuolana.**

No.	Specific Gravity.	Carbonic Acid.	Potash, Soda.	Silica, Alumina, Iron.	Lime	Carbonate of Lime.	Magnesia and Carbonate.	Acids, Chlorides, Phosphates, &c.	Where from.
1	2·652		·62 ·88	25·20 6·16 2·02		58·84	10·38	·48	Utica, Illinois.
2	2·678		·40 12·10	19·66 8·14 3·86		40·54	17·98	·72	Sandusky, Ohio.
3	2·680		1·54 4·64	24·74 16·74 6·80		41·80	4·10	2·22	Cumberland, Md.
4	2·753			17·84 4·60 1·70		58·25	11·16	·74 3·26	Shepherdstown, Va.
5	2·844			18·52 2·18 1·86		43·30	26·04	1·96 4·24	High Falls, Ulster, co., N.Y.
6	2·785			29·34 5·74 1·76		33 54	20·80	1·02 5 80	Do. do.
7	2·822			19·64 7·52 2·38		30·72	35·10	·64 4·10	Do. do.
8	2·761			18·46 4·22 2·32		37·50	35·62	·20 1·68	Do. do.
9	2·786			27·70 2·34 1·26		46·00	17·76	·26 4·02	Do. do.
10		31·00		18·00 5·25	30·20		·20		Sheppy, Eng., cement stone.
11		29·00		17·75 6·00	35·00		·50		Nos. 1 & 2
12		29·77		12·00 8·80	34·08		1·52		Southend, England, do.
13		31·00		24·00 1·31	30·50		1·04		Yorkshire, do.
14		22·75		9.375 17·75	29·25			7·50	Harwich, do.
15			7·0 1·0	57·0 5·0	2·6		1·0		Trass.
16			1·4 4·0	44·5 12·0	8·8		4·7		Puzzuolana.

Nos. 1 to 9 were analyzed by Prof. E. C. Boynton, Miss., and Nos. 10 to 16 by Berthier.

(To be continued.)

THE PATENT LAWS.

At a recent meeting at the Liverpool Hall of Commerce, Lord Stanley, in a speech embracing many topics, made the following remarks upon our Patent Laws:—

"I was chairman of the commission which sat upon the patent law question, during nearly two years. I may, perhaps, remind you that the commission was appointed solely for the purpose of taking into consideration the working of the patent law, and the possibility of introducing into it amendment of detail. We had not the right or the power to go into the larger question, whether it is desirable that patents should in any case be granted for inventions. I may say, for my own part, that I went into the inquiry, accepting the system of patent law as it exists in England as being one which experience had sanctioned, and to which I saw no grave objection. But as evidence was given, and the inquiry proceeded, and it became necessary to turn over the subject in all ways in one's mind, the impression forced itself more and more strongly upon me, and I believe upon others sitting with me—first, that, on the whole, under the actual administration of the law, patents for inventions did more harm than they did good; and next, that no more administrative improvement would be an effectual remedy for the abuses which I saw. I am not saying anything against the abstract justice of the principle upon which

* From Practical Treatises on Limes, Cements, and Mortars. By Gen. Gilmore, U.S.A.

patents are granted. I quite allow that if a valuable invention is made if it is due solely and exclusively to one man (which is a very large assumption), it is quite fair that he should have his reward; and it may be a very reasonable thing that he should take his remuneration in the form of a tax upon the profits of every one using his invention. That is the theory; but when you come to work it in practice it is impossible to overlook certain points. You have an enormous multiplication of patents—patents granted for infinitely minute and trifling inventions. Well, then, it is said, cannot you limit them? Cannot you leave with somebody a discretionary power to see what inventions are worth patenting or not. I do not believe that parliament would grant a discretionary power so enormous; and, if it did that, the tribunal would be upset by the remonstrances and complaints of those who were excluded. Well, then, I start from this assumption—and I believe it is one shared in by the great majority of those who consider the matter—that you cannot in a satisfactory way discriminate between important and unimportant inventions, so as to grant patents to the former and refuse them to the latter. Well, then, what is the evil arising from this enormous multiplication of patents? In the first place, you have a great many which are taken out merely upon speculation, and with no intention on the part of those taking them out to work them. They take them out, that is, upon the calculation that somebody some day will require to use for the purposes of his business the invention which they have patented, and then they can come down upon him, and levy a tax upon him. That is one objection. There is another, that I believe it has become in some branches of the business a system for great employers to buy up every patent they can get hold of —at any rate, that they can get hold of at a reasonable rate—connected with their branch of business. And they do this not merely for the convenience of using it themselves, but because thereby it becomes impossible for any other person to go into that business without here and there infringing some of their patents; and I need not tell you how a multiplicity of patents held by a single employer, who is a large capitalist, and held for that purpose, must act in practically securing a monopoly to the holder. Then there is the objection that, of all judicial investigations, those into patent cases are, perhaps, the most complicated and the most costly; and whatever you do in the way of instituting a special tribunal, or otherwise, in proving the mode of proceeding, I do not believe that you can entirely get rid of that vast expense, for this reason, that the complication lies not in the legal forms, but in the subject matter of the inquiries. Do what you will, trials of patent cases will always, in my belief, be more costly than any others—costly to both parties. It follows, therefore, that a wealthy and powerful employer may infringe the patent of an inventor who is not a capitalist almost without remedy; and, on the other hand, a man of no great means, carrying on a business, if he is sued for the infringement of a patent, can hardly defend himself without the risk of ruin. Then, again, there is another objection to them, of which I do not think sufficient account has been made. It may very often happen that half-a-dozen men are working the same invention about the same time, but that one of these men has got a slight priority, not necessarily a priority of discovery, but a priority in taking out his patent. If he has that in his power to prevent other persons from using that which they may have discovered independently of him—his patent excludes them from the use of their own invention, that invention happening to be coincident with his, unless they can prove—what is exceedingly difficult to prove—that they had it in operation before the time at which his patent was taken. Then, again, I think it is worth notice that in the present day it hardly ever happens that any invention in mechanical matters is solely and exclusively the work of one man. You generally find, I think, in all scientific matters that there are half-a-dozen people upon the same track, and that the priority of one is very slight in point of time, and very often accidental. Supposing that one man hits upon an invention, and keeps it to himself, the probability is that of other men in the same line one will have hit upon the same invention in the same month. This is a circumstance of very considerable importance when you are dealing with the question whether it is proper to give an exclusive reward to the person who happens to be the first to take the invention to the Patent Office. I think there are fair *primâ facie* reasons for an inquiry before the Committee of the House of Commons into the policy of granting patents. I am quite aware that the principle of protecting inventions in this way is recognised throughout Europe and in the United States, and that it has in this country very prominent defenders—I do not mean simply amongst those whose interests are involved—but defenders amongst scientific thinkers. For instance, I recollect a passage in Mr. John Stuart Mill's 'Political Economy,' in which he speaks of the doing away with patents as being, 'not free trade, but the free right of stealing.' I quote that only to show how wide a divergence of opinion there is upon this subject by men whom we must respect, and how necessary it is that it should be fairly and fully considered. Nor is it to be forgotten that there is a very large portion of the bar interested, patent agents are interested, and a large number of persons who have been making profits and advantages to themselves out of this patent system, as I think, at the expense of the public. It seems, therefore, that the question is not rife for any such decisive measure as a proposal to abolish the law of patents, and that the first step is to submit it to the judgment either (which I should think best) of a committee of the House of Commons, or else of a commission of partly practical and partly scientific men, who will look thoroughly into the whole matter. That is the recommendation given in the report of your chamber, and it is a recommendation which I cordially endorse."

THE FINANCE OF ENGINEERING IN INDIA.

By Major J. G. Medley, R.E.

By the finance of engineering, is simply meant that branch of the science which relates to the *cost and returns* of public works. If not so interesting as the strictly professional view of the subject, it is quite as important, though unfortunately engineers are apt to look upon it as something beneath their notice, or at least quite apart from their proper avocations. Hence have arisen insufficient estimates—ill-considered schemes—unremunerative works—railways paying two per cent.—and engineering triumphs like the Thames Tunnel or "the Great Eastern."

It is indeed curious how little attention has been paid to this subject. Lardner's book on Railway Economy was the first scientific investigation of the question of transit financially considered, and Sir A. Cotton's pamphlet on Indian public works, though put forth to advocate the writer's own special ideas, was the first systematic attempt to show the true bearing of public works on the general prosperity of the State, and startled the public like the announcement of some new discovery in science.

It may, therefore, be worth our while to bestow a little attention on the subject, if only to show what data we have and what are wanting, for a proper inquiry into the laws of engineering finance, at least as far as India is concerned.

Like any other question of finance, the subject resolves itself into the two branches of expenditure and receipts. By a proper system of accounts we can apportion and classify the expenditure, but of the receipts in return for, or as a direct consequence of, that expenditure, our data are of the very vaguest. Yet is is only from a just idea of the proportion between the two that the higher problems of the question can be solved: such as, what portion of its revenue a government is justified in expending on public works, or whether it may fairly raise capital to construct them.

As regards the question of expenditure, the present system in use in India, comprises—1st, the preparation of an annual budget, in which the sums to be expended by the several local governments, under various classified headings, are annually allotted, after a due consideration of actual and probable requirements, and of the total amount that can be spared to meet them. Works are classed under the three great headings of military, civil administration, and public improvement—the first two comprehending works required for government purposes, such as military and civil buildings, &c., the last those for the good of the community, such as municipal buildings, roads, canals, and the like.

2. A system of accounts by which the actual work done and its cost are shown, the results being summed up in the annual progress report, which is a corollary to the budget, and shows the performance of the year as compared with the promise. Much difficulty has been practically experienced, and many changes made from time to time in perfecting a system of accounts, which should be satisfactory to Government without being burdensome to the engineer. That a man may be a very good engineer, and yet a very bad accountant, is quite certain. Yet it is

impossible to divest the man who spends money from being answerable for the way in which it has been spent. But that responsibility may yet exist, without compelling the disburser to give an account of it himself, which for a long time was done; until an engineer found that while one-fourth of his time went in doing work, the remaining three-fourths were occupied in writing about it. No system can relieve an engineer of being answerable for the cheapness or dearness of his work; but by giving him an accountant—who will be responsible, not to him, but to Government, for the details of expenditure, as *he* will be for the return for that expenditure—the engineer will be relieved of the most irksome part of his duty, without being freed from his proper responsibility. This system is, I believe, now being introduced, and will no doubt work well.

One much discussed question may just be noticed before quitting this branch of the subject—the question of establishments, as bearing on the total cost of a work. That their amount should bear some proportion to the work done, appears almost an axiom; yet it is not certain that it is even true. As a forcible way of putting the case, it has been asked whether (for instance) it is right that it should cost eight annas to spend a rupee? But there is another way of putting it; whether if it only cost four annas you would not spend two rupees? The late Secretary to Government, in dealing with this question, rightly acknowledged the difficulty of drawing the line between the two items of establishment and labour; and it is indeed difficult to understand how the two can fairly be separated, or why establishment is not considered an integral portion of the total cost of a work. It is true, that to set down the cost of any establishment as out of proportion to the expenditure incurred, may induce a reduction of establishment, but it may also produce an increase of expenditure as an equally effectual mode of diminishing the proportion; and looking at the ultimate aspect of the question, the result to be arrived at is the total cost of a work, and not the cost of its several items, whether labour, materials, or establishment. The effect of the employment of an efficient, and therefore, an expensive establishment, is, or ought to be, a reduction of other expenditure, and provided there is a reduction on the sum total, the details of that sum ought to be a matter of comparative indifference.

Having said thus much on the question of expenditure, let us turn to the other side of the account, and inquire into the receipts.

Public works may pay in two ways—1st, They may pay the promoters in the shape of a direct return, such as in the case of tolls on a road, water-rent from a canal, or traffic receipts on a railway.

Of the above, as regards India, Government has made the roads, and, anxious to remove all hindrances to free traffic, has given up all tolls, trusting to receive back its money indirectly, in the shape of customs' dues or otherwise, through the general prosperity of the community. Where roads are made by private individuals, which may yet come to pass in India, the principle on which tolls should be levied is sufficiently obvious without further explanation.

Railways are yet in their infancy, and Government has but a part-ownership in them. From the latest returns available, it appears that the traffic receipts on all open Indian lines, of more than 100 miles in length, average in round numbers 10,000 rupees per annum per mile of opened line. If we estimate the working expenses at 50* per cent. of the gross receipts, we shall not be far wrong; and the average estimated cost may be taken at 1,35,000 rupees per mile, showing a clear return of less than 4 per cent. per annum on the capital expended. This is not very encouraging in a financial point of view, but it must be remembered that the traffic is still only partially developed, and that until the great lines are opened throughout, no fair average of results can be struck. After that time, and especially as roads and branch railways are made to feed the main lines, a considerable extension of traffic may be looked for, but it is after all by the indirect returns that the value of railways to India must for a long time be judged.

As to the direct returns from canals and other works of irrigation, it appears that on the only large canals in upper India where irrigation has as yet been fully developed (the E. and W. Jumna canals), the net annual profit is rather more than 10 per cent. on the total cost. But it is not probable that this percentage of profit will be realised by the new canals for many years to come. The strict financial reckoning now exacted by Government, in which the interest of the capital is reckoned from the commencement of a work, shows that in the case of the Eastern Jumna canal, that work has already defrayed the whole cost of its maintenance and repairs, *plus* 5 per cent. interest on the capital, leaving a balance in hand at credit of Government. Major Brownlow, the late superintendent of this canal, has reckoned the cost of its construction at 6·5 Rs. per acre of average area irrigated, and the maintenance and establishment at 7 annas per acre. Colonel Rundall, R.E., gives Madras rates as 8·3 Rs. for construction, and 6·6 annas for maintenance, per acre.

Madras works are, however, believed to be generally more profitable than in this presidency. In a late minute on irrigation by H. E. Sir W. Denison, the annual cost of the water to Government is reckoned at 1 rupee per 4200 cubic yards, the supply being spread over a period of about three months; while the value of this water is reckoned at 1 rupee per 1000 cubic yards. Capitalizing the above cost at 5 per cent., the returns show a profit of more than 20 per cent. on the outlay.

2. Public works may pay indirectly.

The returns in this case are more difficult to determine, and the data are indeed most imperfect, but it will be useful to show what we have, and what are wanting.

Roads operate indirectly—1st, by diminishing the cost of transport; 2nd, by setting free a large amount of labour, which may be employed otherwise

The Postmaster-General, N.W. Provinces, in 1850, calculated that the actual haulage of a ton of goods by the bullock-train cost Government one anna per ton per mile on a metalled, and three annas on an unmetalled road, exclusive of prime cost and wear and tear of animals and vehicles.* I have no returns of traffic on any roads, but if the above calculations be accepted, (and they were made from very fair data,) and taking the cost of a metalled and bridged road at an average of 7500 rupees per mile, the cost of repairing it at 300 rupees annually, and interest of money at 5 per cent., it would appear that on any line on which there is traffic to the amount of 5400 tons yearly, it would pay to construct a metalled road.

As to the increase to the wealth of a district through which a road runs, or the extent to which Government, as the road-constructor, benefits by that wealth, I have no means of ascertaining it, but I believe such data might be collected in certain districts, and would be very valuable.

If the cost of carriage is diminished by a metalled road, it is needless to point out how much more this is the case in respect to a railway.† In the back settlements of America this fact alone has created railways, not as with us, as luxuries, but as the first necessities of the settler and the first step towards civilization. Rude as they are, often consisting of flat iron bars spiked down to rough logs of timber, laid without ballast on the natural surface of the ground, they answer their purpose and pay indirectly, by giving the makers facilities of transport for their produce, and by enhancing the value of their land.

Though the same facilities of construction (in the abundance of timber) do not exist in India, yet we have a counterbalancing advantage in the comparative cheapness and abundance of labour, and at least as strong inducements to open up communication between remote districts. We have indeed a further inducement, which it is astonishing we have until lately been so slow to recognize—I mean the facility of transport for troops, artillery and stores, which, to a Government in our position, is an absolutely incalculable advantage. The strongest military government that the world has ever seen (the Roman) were not slow to perceive the importance of this—their first step on the acquisition of a new country being to drive a broad military road into the heart of it from the nearest cantonment, made by the soldiers themselves.

And this leads me to remark (though it has often been the subject of remark before) on the feasibility of employing a considerable portion of our army, English and native, in the

* It is over this at present, I believe, but will probably be reduced below this percentage before long.

* Sir A. Cotton gives the following as the actual cost of various kinds of transit in India, per ton per mile:—

Sea navigation	5 to 8 pie (⅝d. to 1d.)
River do.	4 pie, or ½d.
Completed roads	1 anna, or 1½d.
Imperfect do.	2 annas, or 3d.
Unimproved tracks	3 annas, or 4½d.

He also gives the actual traffic on the first 125 miles of the Great Western Road from Madras as 100,000 tons yearly.

† Dr. Lardner gives the actual cost of transit of goods per ton per mile on English railways at 1·11d. The rates charged on Indian lines vary from 7 pie (⅞d.) to 5 annas (7½d.) What the actual cost is I do not know.

construction of public works; pressing it, as I would, as an important step in financial economy, towards remedying the two greatest acknowledged drawbacks to improvement in India—the (necessarily) excessive military expenditure, and the want of means of internal communication; for, as the increase of roads would lessen the cost of military transport, so the employment of soldiers would increase the roads. In round numbers we have 70,000 English and 130,000 Native soldiers in India, whereof I would urge that one-half might be employed for six months out of the twelve, in other than regimental work, not only without any sacrifice of efficiency, but with a positive increase to it,* as few can doubt that the men who were well and constantly employed all the year round, off as well as on parade, who could use the spade and pickaxe, the saw and the hammer, would be the best men for the real hard work of a campaign. I am fully aware of the difficulties in the way, of the requirements of parade and rifle drill, &c., but making every allowance for that, I think that the proportion above estimated (only *one-fourth* the strength of the army annually) might be employed as suggested. Now, the money value of this unemployed labour, cannot at the lowest estimate be put down at less than 25 lakhs of rupees, or a quarter of a million sterling, whereof one-half should go into the pockets of the soldiers as working pay, and the rest should be clear profit to Government. This half sum represents 170 miles of first class road annually,

Closely allied to this subject, are the indirect returns which may be said to arise from good barracks, and such like expenditure, which is commonly set down as unremunerative. For the value† of this we must go to sanitary statistics, but, as I have hinted above, the question is so mixed up with other things affecting the health of the soldier, that it is impossible to say how much saving of life (*i. e.*, of money) is due to good barracks in lieu of bad ones. There are some of our older stations, however, whose statistics, if available, would doubtless throw some light on this head, and allow us to estimate to a very fair approximation the capital which might be employed in good dwellings, whose interest would be the improvement of health in the dwellers. As a practical question, however, it may be said to be unnecessary now, Government being fully alive to the duty, as well as economy, of not sparing money in this direction, as has been shown in all the cantonments lately built.

As to the indirect returns of works of irrigation, we have some statistics which will serve to show their immense value and importance. These indirect returns, which can be measured or estimated, consist in the increased land revenue obtainable by Government from the districts benefited, either by waste land being brought under cultivation, or by the difference in value between wet and dry cultivation,‡ as it is technically termed.

From a comparison of data on five first-class canals in Upper India, constructed, in hand, or estimated, it appears that the average prime cost of a cubic foot of water per second of discharge at the heads is 4000 rupees; that the average annual value of a cubic foot (including the increase to land revenue), is 750 rupees; and the average annual expenditure per cubic foot is 120 rupees. So that the clear return to Government is 630 rupees, or nearly 16 per cent. annually on the capital invested, besides the general benefit to the community.

The returns from Madras canals are more favourable than this, being estimated by Col. Baird Smith, in one district, at 20, and in another at 23 per cent annually, on the capital invested; and by Sir A. Cotton, and others, at very much more than this.

There are also other indirect returns which cannot be reduced to figures, such as the saving in remissions of revenue, which are often forced on Government during years of drought, in districts where there is no artificial irrigation;§ besides, as before remarked, the general prosperity of the community, a prosperity in which Government necessarily shares, if only by the increased consumption of taxable commodities.

In the above remarks I have only made a passing allusion to the general question of the execution of public works by Government. It is indeed too important a question to be disposed of in an off-hand manner, yet people often think that as soon as they have proved public works to be remunerative, it follows as a matter of course that it is the duty of Government to construct them; and that, if it has not got the money, it ought to borrow it for the express purpose. Without entering too far into such a large question, it may be sufficient here to remark—1st, that though it may be the right or interest of the Government to undertake such works, it does not follow it is part of its duty, and that Government has already enough of its own proper functions to perform; 2nd, that it is a pretty generally admitted maxim that the construction of public works is much better left to private enterprise, and that even in the exceptional case of India the onus of proof at least lies with those who would contend for a different principle; 3rd, in answer to those who ask for public work loans on the ground that it is unfair to tax the present generation alone for benefits equally shared by a future one, it may be answered that it is at least as unfair to plunge a future generation into debt on account of speculations in which they cannot possibly have a voice. Government has in effect been compelled to try the experiment, and the result of it in the railway guarantee system is not encouraging, nor is it likely to be repeated. With the progress of education the people's eyes will be opened to working together for their own benefit; the influx of capital into the country within the last seven years has been enormous, and it is to be hoped we may soon see railways, roads, and canals constructed under the auspices of intelligent and respectable bodies of native proprietors.

Here for the present we must stop. I am quite aware of the imperfect manner in which such an important subject has been treated, but shall be content if these few remarks may induce others to collect data and compare results, which may be useful in elucidating the laws on which the finance of Indian engineering should be based.

* The great cause of sickness and mortality in the Anglo-Indian Army is—not drunkenness (that is an effect only of other causes)—not bad barracks or unsuitable food—not exposure to the sun (for the classes of men most exposed to the sun in India are generally the healthiest)—but want of occupation. I am aware of the claims of regimental workshops on much of this unoccupied time, and if they could be put on a proper footing, would be the first to advocate them. If the whole of the accoutrements, barrack furniture and fittings, &c., could be made by the men, sharing the profits with Government, no one can doubt the advantage to both. But I hold that any system of amateur workshops is simply illusory - it is playing at work. It is well known that the French Army in Algeria is largely employed as above suggested.

† The cost of housing the European troops in the Punjab cantonments was certainly not less than 800 Rs. per man.

‡ Sir A. Cotton reckons this difference in the case of rice at 9 Rs. per acre, computed on the gross value of the crop. Col. Baird Smith estimated it on the Western Jumna Canal at 364 Rs. per square mile for land revenue only, making a total profit (including water-rent) of 36 per cent.

§ The value of the crops produced by the Ganges Canal alone during 1861-62 was one and a quarter million sterling. The water-rent paid to Government was £70,000.

DURHAM CATHEDRAL.

At the meeting of the British Archæological Association, at Durham, the following account of Durham Cathedral was given by Mr. Gordon M. Hills, the sub-treasurer of the Association.

Mr. Hills said they were assembled to examine and to learn, from the magnificent buildings which had been so kindly laid open to them, what they could of true magnificence in church architecture; for he thought they would generally agree with him that not one of their cathedrals, though perhaps it might be surpassed in general beauty and ornamentation of the parts, as in the case of Lincoln, had that air of solemnity and dignity which was to be found in Durham cathedral. The story of St. Cuthbert, the patron saint of the Cathedral, was a very long one; and therefore, he thought, it would be best for him to begin with that part of it merely which related to his connection with the city of Durham, and his arrival there. It was in the year 995, after various peregrinations, and after having been driven from Chester-le-street, that the remains of the saint were brought to Durham by Aldune, who began at once to erect a church of a temporary nature of branches and leaves, which was afterwards replaced by one of wood. This also was temporary, as he afterwards proceeded to erect a stone church, which was three years in building, having been completed in 999; and immediately after the body of the saint was placed in the church. Before proceeding on their course through the cathedral, he should say a few words on the nature of the buildings they would see, so that they might obtain some general notion of them. This church of Aldune's was one of secular canons. It was not until one hundred years afterwards that Benedictine monks—the only monks in England at this period—were introduced. They proceeded to erect buildings for their accommodation, and Mr. Hills said he might here mention that the remains of these buildings were to be found in the substructure of the deanery, and of the refectory which occupied that part of the building where they then were. Mr. Hills then instituted a comparison between the Monastery of Bury St. Edmunds, Fountains Abbey, and the buildings at Durham, showing the agreement in the arrangement of those edifices. They found that at Durham there had existed all the arrangements complete of a Benedictine monastery. The general plan of the cathedral as now existing was that of a cross, with a remarkable appendage at the eastern end of the Nine Altars chapel, and at the western end of the Galilee chapel. They had found a similar appendage at Fountains Abbey, where also the chapel was called the Nine Altars. The church, as it now stood, was begun about ten years after the introduction of the Benedictine monks, who were introduced in 1083. There must, however, have been a smaller building in existence at the time, as they found that Carileph, who began to build the church, died two years after, and was buried in the chapter-house. They were told that when his successor, Ralph Flambard, began to pull down Aldune's church he arrived at the tomb of St. Cuthbert, and caused the body of the saint to be removed to the cloister; so that the cloisters must have been in existence at that period. Although Carileph lived to see little of his work completed, it was progressing rapidly at the eastern part at the time of his death. Regarding the form of this eastern end, there were two opinions entertained, but he himself did not pretend to give an opinion on either. Some persons thought that the eastern portion had an apsidal end taking in the whole breadth; while others thought there had been an apse for the nave and one for each of the aisles. The church was raised to the roof under Ralph Flambard, who succeeded Carileph, and who held the see from 1099 to 1128. Therefore, although they had no record of the completion of the church, it must have been completed after that period. He should have to draw their particular attention to the vaulting of the nave, which he had no doubt was not a consecutive work with the rest of the church. They would see that it would be a singular thing indeed if it were so, for the style was of the period which followed after the time of Ralph Flambard. He then called their attention to the Chapter-house, a very remarkable building, which, he was sorry to say, they could see very little of now. It was built before Bishop Pudsey, who succeeded to the see in 1154. It was remarkable for its apsidal end, the whole of which was pulled down a few years ago, and converted into a square room. There were yet interesting remains of that apse in the room in which they then were. These were the three large corbels—figures sustaining a weight on their heads, or according to the Greek, caryatides,—from which the vaulting of the arches sprung. There had been a fourth, but he did not know what had become of it. Before leaving the library he called their attention to a drawing of Carileph's church, by Mr. Robson, late architect to the dean and chapter, by which they would see the changes effected in after times in the upper parts of the building. (The party then assembled in the nave of the cathedral.)

Mr. Hills said they were now in that part of the church which was erected by Ralph Flambard, and which extended from the cross arch to the west end, being the nave of the church. He said he need not call their attention to the extraordinary massive construction of the piers and arches—those circular piers being no less than 25 ft. 6 in. in circumference—but what he wished to point out was that in the eastern part of the nave the arches had no ornamentation whatever, having only plain moulding; while at the bay in which they then stood (opposite the main entrance) they had chevron moulding, from which place it was continued to the end of the church. They found that the vaulting was constructed with the same ornament, but with this difference between the two, that while everything to the top of the walls was round, or what was called the Norman arch, the vaulting itself was of the pointed form. That had led to some misapprehension as to the date of the vaulting. He could not trace the evidence as to the date of the vaulting further back than was afforded by the writings of Brown Willis in the last century, who told them that Prior Melsonby vaulted the nave of the church (between 1233 and 1244); but when they came to examine it, they would find it impossible to believe that this was so. He thought they must rather conclude, seeing the way in which the vaulting harmonised with the ornamentation of that part of the body of the church, that having carried up the walls under Ralph Flambard, they commenced to roof, and carried it on in the same ornamental style as they had commenced the church. He thought there could be no doubt that it was in Bishop Pudsey's time that the vaulting was put on; and one reason which led them to connect it with him was the circumstance that the ornamentation was similar to that found in the Galilee or Lady-chapel, which was constructed by him. The nave now was very bare indeed of ornamentation to what it was when first devoted to worship down to the period of the Reformation. At the latter period, the magnificent rood screen, and an altar called the Jesus altar, were removed. The rood screen was considered the choicest in the country.

Having referred to the several altars which stood in that part of the church, and the spot where the sanctuary was situated, he called their attention to the line of blue marble in the pavement extending between the northern and southern doors. That was a great peculiarity in the building, for to the east of that mark, where he saw a great many ladies now standing, women were never permitted to go, down to the time of the Reformation. Various reasons had been given for such exclusion, which it was hardly worth while to quote. It might, however, be stated, and it seemed to have arisen from the misconduct of certain monks at one of St. Cuthbert's monasteries to which a nunnery was attached; and he resolved that men and women should never again be associated at one of his monasteries. The mark, however, might have had another meaning originally, for he had a strong suspicion that in early times there was some intention of shutting off the choir at that part.

The Galilee chapel, at the west of the main edifice, was next visited. It was erected by Hugh Pudsey, possibly towards the conclusion of his episcopate, which begun in 1153, and lasted nearly forty years. They would see that in placing this building there he stopped up and enclosed the ancient west door of the church. They were told he was led to erect the building for the worship of the Virgin Mary, and for the use of females, who, being excluded from the rest of the church, it was necessary to provide for them some other place. This was perhaps one of the earliest so erected lady-chapels; and he need not call their attention to the extreme beauty of its arrangements, although there had been many alterations since its first erection. Perhaps one object which Bishop Pudsey had in erecting that chapel was to give a becoming shrine to the remains of the Venerable Bede. Bishop Langley, before the Reformation, caused a considerable alteration to be made in front of the great altar, and his own to be erected there; and it was to him they owed the construction of the new flat roof, the roof having previously been pointed; and he also put in windows of a pointed character all through the west front, and constructed the massive buttresses overlooking the river banks. The latest work which had been carried out on that part of the building had been the reconstruction of the north side. The work was now finished, and he thought they had every reason to be satisfied with the admirable style in which it had been executed.

The Nine Altars' Chapel then came under attention, where Mr. Hils called attention to the magnificent screen dividing the choir from the chapel. In the centre of the screen was a large marble slab; beneath rested the body of the saint. Right in the middle of the quadrangular space to the east of the screen was placed the shrine of the saint himself. The question of the identity of the body of the saint was one that was raised in very early times; for there were some people who disbelieved that the body could have been preserved incorrupt for so many years. When Abbot Turgot, by whom the principal part of the church was erected, under Bishop Carileph, prepared the place for the reception of the body of the saint, and caused an examination of the remains to be made, it was found that the body was cased in more than one coffin, and carefully protected in the internal coffin with hides, the body itself being wrapped in cloths, which were pressed so close that it is said by Reginald that he could not in any place insert his finger betwixt the cloth and the body. Mr. Hills thought it was an opinion pretty well received now amongst medical men that such a mode of preservation would effectually retain the form of the body in an almost life-like appearance for a number of years; and that it was the identical body of the saint which had so long been preserved was considered then to be conclusively shown, because some hundred years before it was reputed to be so life-like that the hair and nails were said to have grown upon it, and a certain monk was stated to have been deputed to trim the hair and nails, and Reginald said that in the coffin were found the scissors and comb which he had used. On the suppression of the monasteries in the reign of Henry VIII., the body was again examined. On breaking up the shrine the commissioners were surprised to find the body so perfectly kept, and orders were afterwards given for its re-interment. It lay undisturbed until 1827, when a gentleman, anxious to find out if the body was still in a state of preservation, caused the ground to be opened out; and although they came upon the coffin and a series of inner coffins, much broken, there was sufficient to show that they were those described by Reginald the monk. They found that the form of the body had been lost and reduced to a mere skeleton, but amongst a number of relics they came upon the very comb which had been spoken of so many hundred years before, and which was now preserved in the library of the refectory.

Richard Poore, Bishop of Salisbury, afterwards became Bishop of Durham in 1227; and they found that the architecture of the Nine Altars, viz., 1242, was much like that of the church which they studied at their Congress at Salisbury, and agreed in a remarkable manner with the Nine Altars at Fountains. He then referred to the Nine Altars, now removed, which gave the name to the chapel, and the saints to whom they were dedicated, stating that the altars were originally divided from each other by oak screens of elaborate tabernacle work, and were each fitted up with ambries, chalices, cups, and everything of the most costly description. In inspecting the choir, he said that that was the most ancient part of the whole building, being that which was begun and erected in Bishop Carileph's time; and excepting the decoration, or chevron moulding at the west end, they would see there was little difference in its style from that of the rest of the building. The magnificent erection on the south side of the choir, in what was called the Decorated style, was the tomb of Bishop Hatfield, erected in his own time; and upon it he placed his own throne, which was still used as the throne of the Bishops of Durham. In the transepts, Mr. Hills said that that part of the cathedral, as they would understand from the sketch by Mr. Robson, was originally finished with a lofty tower, as they now saw it. It had, in fact, the ordinary low Norman tower. That tower had seen many vicissitudes, for not only was the Norman tower displaced, but a tower built by Hugh Darlington (successor of Melsonby) had also entirely disappeared. It was struck by lightning, and in part destroyed, and shortly after that the rest of the tower was found going to ruin. Of the history of the tower, as they now saw it, nothing was known until it was brought to light by Mr. Raine, who proved that it had been erected about the middle of the 15th century. They would see that it had been begun at a time when what was called Perpendicular work prevailed. Immediately above the Norman arches, they would notice the extraordinary bulk of the columns upon which it was supported; and he must say the bulk was no more than it required, as the weight upon them was nearly 11,000 tons. The chevron moulding of the vaulting was found existing in the south transept, while it was absent in the north, showing that the north transept was finished first.

THE WROUGHT-IRON ROAD BRIDGES OF THE CHARING-CROSS RAILWAY.*

By M. Parkes.

(*With Engravings.*)

Four similar box girder bridges will now be described—namely, Sutton-street, Waterloo-road, (main line), Blackfriars-road, and Southwark-road. In Plate 29, the proportions are those of Blackfriars-road bridge. Fig. 13 is a half transverse section. Fig. 11 is an elevation of a portion of a girder, showing rollers, a cross girder in position, and a portion of cornice.

Following the same order observed with the other bridges, we commence with Sutton-street. The main girders in this case are similar in every dimension except length; one girder being 111 ft. 6 in., and the other 110 ft. 6 in. The depth at centre is 7 ft. 8 in., and at the ends 6 ft. The top flange, 2 ft. 4 in. wide, is built up of four $\frac{5}{8}$-plates at centre, reduced to three at ends; the bottom flange, 2 ft. 2 in. wide, is built up of one $\frac{3}{4}$ and three $\frac{5}{8}$ plates at centre, reduced to one $\frac{3}{4}$ and two $\frac{5}{8}$ at ends. Each flange is connected to the webs by four angle-irons, $6\times6\times\frac{5}{8}$. The ordinary width of web plates is 3 ft. Five plates at either end of each line of webs are $\frac{5}{8}$ thick, and the intermediate one $\frac{1}{4}$. The vertical joints are connected alternately by a T iron and strip, and two strips; the size of T iron is 6 ft. $\times$ 3 in. $\times\frac{5}{8}$ in. and of the strips, $6\times\frac{5}{8}$. The T irons are set over the longitudinal angle-irons; but the strips merely butt.

One end of each main girder rests on eight rollers $4\frac{1}{2}$ in. diameter; the bearing and bed plates are of cast-iron 2 in. thick; at the other end a bearing plate, 4 ft. 6 in. $\times$ 3 ft. $\times\frac{3}{4}$ in., is provided, and flush riveted to under-side of girder. The distance between top flanges of main girders, or, in other words, the clear width of bridge, is 35 ft. 8 in. The cross girders are 2 feet deep, but vary in width from 15 in to 7 in. They are riveted to underside of main girders, 4 feet apart, centre to centre. The 15 in. girders are attached by sixteen rivets, 1 in. diameter, at each end.

In consequence of the great skew of bridge, five cross girders only are attached to both main girders; these are 40 ft. 2 in. long, with top and bottom flanges $15\times\frac{1}{2}$, each connected to the $\frac{1}{4}$ web by two angle-irons, $4\times4\times\frac{1}{2}$; the webs are stiffened by vertical T irons, which divide the length of girder into seven panels. The roadway is on the second system, shown in Fig. 13.

In this bridge a facia of $\frac{1}{4}$ plate was riveted to vertical angle-irons on ends of cross girders; a flat strip was also riveted to bottom of facia plate. The weight of both main girders is 90 tons 8 cwt.; of all the cross girders, 55 tons 15 cwt.; and of the whole bridge, 178 tons 5 cwt.

Waterloo-road.—The main line is carried over this road by two girders, each 121 feet long: they are 11 ft. 8 in. deep at centre, and 9 ft. 10 in. at ends. Both flanges are 2 ft. 6 in. wide; the top is built up of five $\frac{5}{8}$-plates at centre, reduced to three at ends; the bottom is built up of one $\frac{3}{4}$ and four $\frac{5}{8}$ plates at centre, reduced to one $\frac{3}{4}$ and two $\frac{5}{8}$ at ends.

Each flange is connected to the webs by four angle-irons $6\times6\times\frac{5}{8}$. The ordinary width of webs is 3 feet, and the arrangement of vertical joints the same as in the last example: six plates at either end of each line of webs are $\frac{5}{8}$ thick, and the remainder $\frac{1}{4}$. The clear width of bridge is 40 ft. 6 in., to allow for the curve of line.

The cross girders are riveted to main girders 4 feet apart, centre to centre; they are 2 feet deep, with flanges each 15 in. wide, and in two $\frac{1}{2}$-inch thicknesses; two angle-irons, $4\times4\times\frac{3}{4}$, connect each flange to $\frac{1}{4}$ web. To the top flange a plate 19 inches wide $\times\frac{1}{4}$ is also riveted for attaching road plates on the third system. Figs. 6 and 8. One end of each main girder is provided with rollers, as shown in Figs. 11 and 12. The weight of both main girders is 125 tons 2 cwt.; of all the cross girders 119 tons 8 cwt.; and of the whole bridge 276 tons 15 cwt.

Blackfriars-road.—One of the abutments of this bridge is at right angles to line, and the other only slightly out of square. This and Waterloo branch bridge are the only ones in which all the cross girders are connected to both main girders.

The main box girders, which are 110 feet long, have a central and end depth of 10 ft. 6 in. and 8 ft. 10 in.: both flanges are 2 ft. 6 in. wide; the top is built up of five nine-sixteenths plate at centre, reduced to four at ends; the bottom is built up of one $\frac{3}{4}$ and four nine-sixteenths plates at centre, reduced to one $\frac{3}{4}$ and three nine-sixteenths at ends. Each flange is connected to the webs by four angle-irons $6\times6\times$ nine-sixteenths: eight in the whole section. The two end web plates at either end of each line are 2 feet wide, and the intermediate ones are 3 ft. The girders are braced internally at seven points by a system of lattice bars, shown in Fig. 13; the bars are $2\times\frac{5}{8}$, and are riveted to T irons, which, in this case, are substituted for the internal strips. The cross-girders, twenty-four in number, have flanges 15 inches wide $\times\frac{1}{2}$ thick, riveted to a $\frac{1}{2}$ web by $4\times4\times\frac{1}{2}$ angle-iron: they are 2 feet deep, and each end is riveted to the main girder with 20-in. rivets; the web is divided by vertical T irons into eight panels.

The weight of both main girders is $106\frac{1}{2}$ tons; of all the cross girders, 71 tons 12 cwt.; and of the whole bridge 214 tons 17 cwt. The roadway is on the second system, Fig. 13.

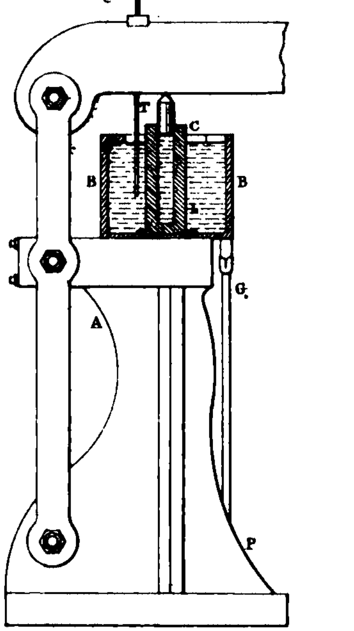
Southwark-bridge-road.—In this case, the main girders are 135 feet and 82 feet long respectively: the cross girders and road plates similar to Blackfriars, excepting, of course, the difference in section of short cross girders for skew ends of bridge.

The dimensions of the 135 feet girder are as follows: the depth at centre is 12 feet, and at ends 9 ft. 8 in.: both flanges are 2 ft. 6 in. wide; the top is built up of five $\frac{5}{8}$ plates at centre, reduced to three at ends; the bottom is built up of one $\frac{11}{16}$ and four $\frac{5}{8}$ plates at centre, reduced to one $\frac{11}{16}$ and two $\frac{5}{8}$ at ends. Each flange is connected to the webs by four angle-irons $6\times6\times\frac{5}{8}$. The webs and their vertical connexions are similar to those in the Blackfriars-road-bridge. All the vertical rivets are 1 inch and the horizontal $\frac{3}{4}$-inch diameter.

The 82-feet girder has a central and end depth of 9 feet and 7 ft. 6 in respectively: each flange is 2 ft. 2 in. wide, and connected to webs by four angle-irons $4\times4\times\frac{1}{2}$; the top is built up of four $\frac{5}{8}$ plates at centre, reduced to three at ends; the bottom is built

* Continued from page 242.

Fig. 4.



Figs. 11. 12 & 13. RAILWAY BRIDGE, BLACKFRIARS ROAD.

Fig. 12.

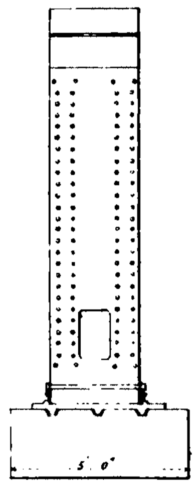
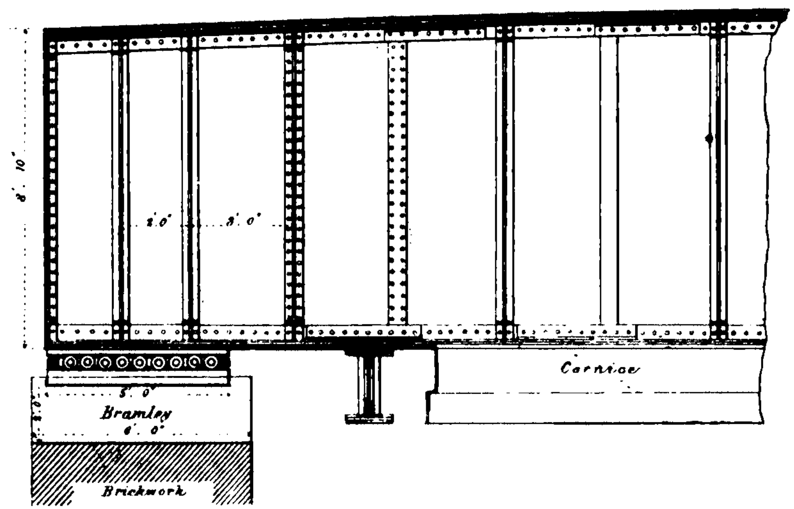


Fig. 11.



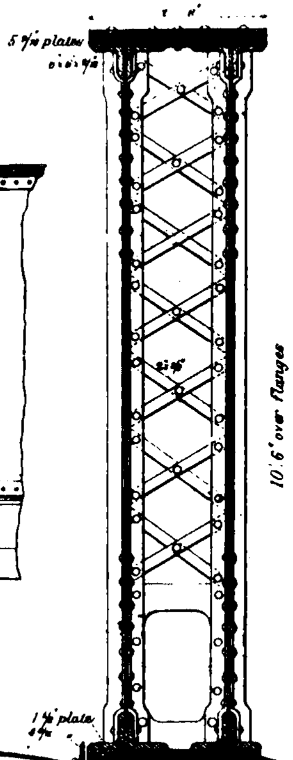
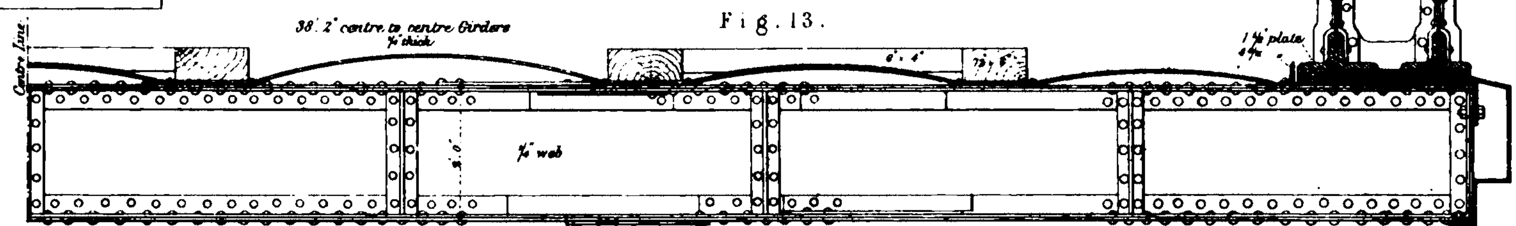


Fig. 13.



Figs. 1. 2. 3 & 4. FAIRBAIRN'S EXPERIMENTS ON DEEP SEA CABLES.

Fig. 1.

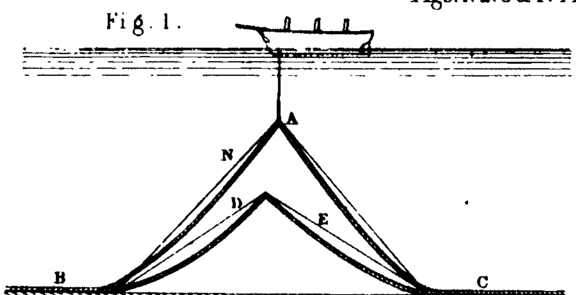


Fig. 2.

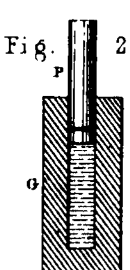
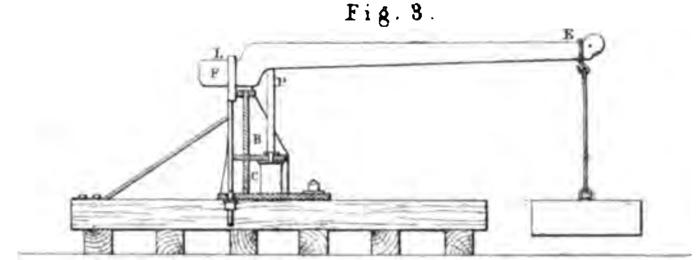
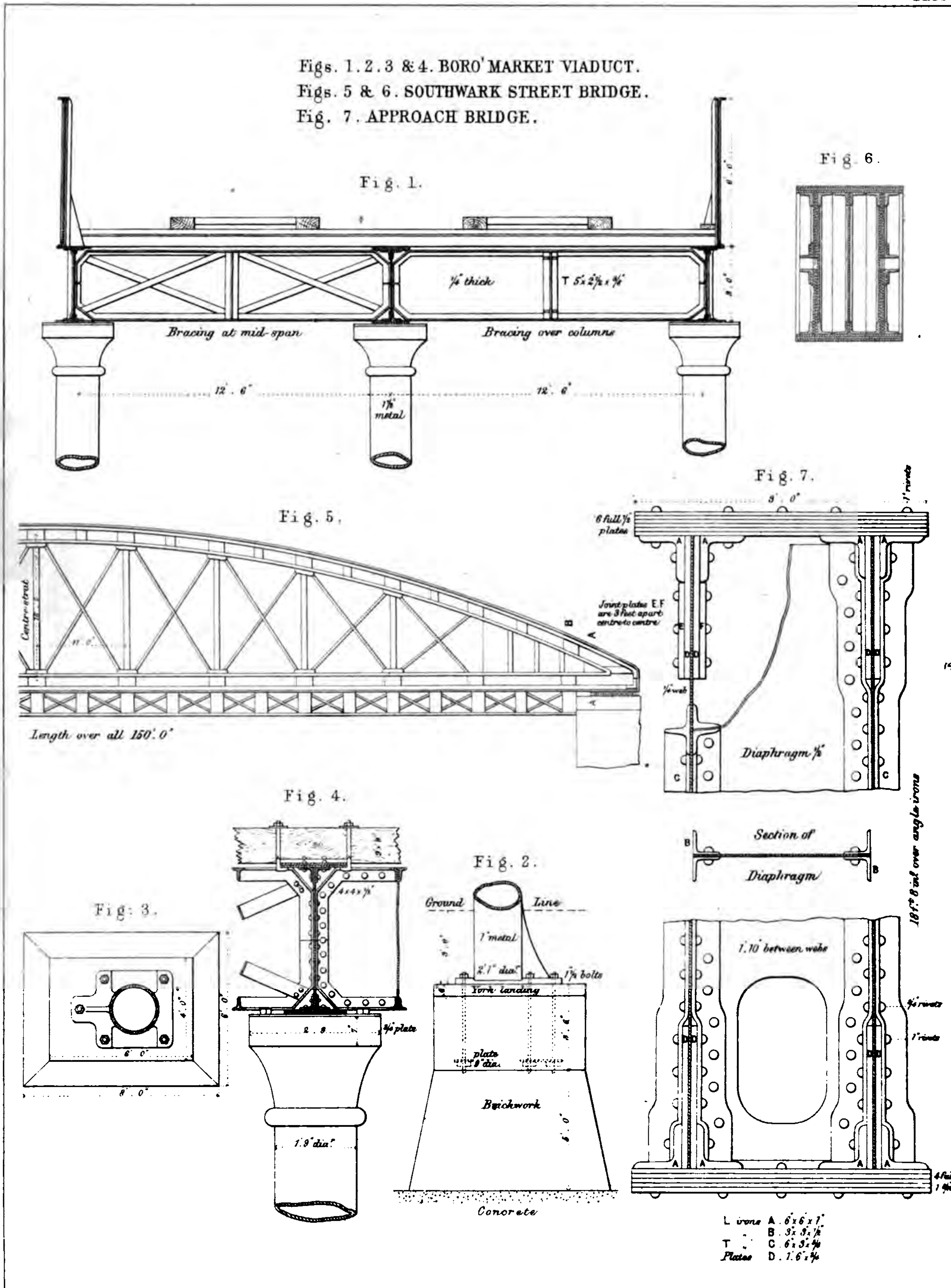


Fig. 3.



Figs. 1. 2. 3 & 4. BORO' MARKET VIADUCT.
Figs. 5 & 6. SOUTHWARK STREET BRIDGE.
Fig. 7. APPROACH BRIDGE.



J R Jobbins

up of one ¾ and three ⅝ at centre, reduced to one ¾ and two ⅝ at ends. The webs are three-sixteenths thick, but the vertical T irons and strips are the same as in other girders. Both girders are braced internally with lattice bars 2×⅝, as shown in Fig. 13.

The long cross girders, or those connected to both main girders and the road plating, are the same as in Blackfriars-bridge. A cast-iron cornice is bolted to ends of cross girders, as shown in Figs. 11 and 13.

The weight of the 135-feet girder is 68½ tons, of the 82-feet girder 27 tons 3 cwt., and of the whole bridge, 199 tons.

The next bridge we have to notice is the one over Southwark-street, which, as stated in the introductory sketch, is a structure consisting mainly of two bowstring girders, having riveted and bolted to them cross girders for forming platform. In Plate 28, Fig. 5. is a half elevation of one side of bridge, and Fig. 6 is a transverse section through AA in Fig. 5. In Plate 29, Fig. 1, is a transverse section at centre of a girder; Fig. 2 is an elevation of girder at centre strut; and Fig. 3 is a section of struts.

Referring to Plate 28, Fig. 5, it will be seen that each bow-string is composed of four primary members—the bow, the tie, the system of struts, and the system of diagonals: the length over all is 150 feet, and the distance, centre of bow to centre of tie at middle span is 18 feet, and width of bow 3 feet; the bow and tie are two troughs of similar section, the first being inverted, and are constructed thus:—

The bottom of the trough is built up of three ⅝-plates 3 feet wide, in ordinary lengths of 5 ft. 8 in., breaking joint in the usual way; each side which is 2 feet deep, and formed of two ⅝ plates, is riveted to this bottom by two angle-irons 5×5×1 in. A reverse angle-iron, as shown in Plate 29, Figs. 1 and 2, is also riveted to sides externally.

The struts nine in number, may be described as small lattice girders, 1 ft. 7½ in. deep, with equal flanges 8 inches wide×⅝ thick. To each flange two angle-irons 3×3×⅝ are riveted back to back, between which the lattice bars 2½×½ are also riveted. For a length of 18 inches at each end a ½-plate is substituted for the lattice bars. The struts are riveted together with ⅝ rivets, and to bow and tie with twenty-four 1-inch rivets in each case.

Flat bars 6 inches wide constitute the diagonals: the twelve central pairs are ¾ thick, and the remainder ⅝. Excepting in eight cases, they are connected to bow and tie by gib and cotter. The eight cases referred to are the ends of end diagonals, next ends of girders, which are attached by six rivets 1 inch diameter.

In this, as in other structures, the junctions of the various members have required the greatest synthetic skill. The two important cases are, first, the connexion of bow and tie; second, the connexion of bow, tie, struts, and diagonals together. To accomplish the first, the laminated plates and angle-irons of bow are made to butt on those of tie, a small angle-iron corner piece being riveted at junction of angle-irons; the reverse angle-irons of bow and tie butt, and are connected by a V shaped joint plate. The space between bow and tie, for a distance of 14 ft. 6 in., is filled in with ½-inch plate, which butts against the extremities of the arms of angle-irons of bow and tie, and extends to end of girder; the vertical joints of this plating are connected by an interior and exterior strip 8×¾. A front plate is also riveted to this plating by T iron 3×3×½. The side plates of bow and tie butt, and the joints are covered by the ½-inch plating internally, and a strip 8×¾ externally. The junction of bow and tie is further strengthened by a ½-inch plate riveted to bow and tie by angle-iron 5×5×1, and extending for a distance of 9 feet from end of girder.

To make the second connection—namely, that of bow, tie, struts, and diagonals together, a plan was adopted, consisting of first riveting to sides of trough, internally, with countersunk rivets, a plate 2 ft. 8 in. long, 2 ft. 3 in. wide, with slot holes at upper corners to correspond with diagonals; the holes corresponding with those in strut are left open. The strut is next introduced, to the inner side of each flange of which are applied two wing plates, with six rivet holes and slot holes corresponding to those in one half of the first mentioned plate. The whole are then riveted together with 12 rivets 1 inch diameter on each side of strut. The plate next sides of trough and the wing plates are ¾ inch thick. The external side-joint plates of bow and tie, and the vertical and horizontal joint strips at end of girder, are all shown in position in Plate 29, Fig. 5.

One end of each girder is placed on eight rollers 6 inches diameter, and provided with bearing and bed plates of cast-iron 2 inches thick. The rivets are all 1 inch diameter and 4 inches pitch, excepting those through ½-inch plating, and 3×3×½ angle-iron or joint strips, which are ⅝ inch.

There are thirty-six cross-girders; twenty-two of these are box and the remainder single web. Ten cross girders only are connected to both bow-strings, which are of the box type; and fourteen out of the twenty-two box are of heavier section than the remainder; but the single web are all one section. The depth of all the cross girders is 3 ft. 3 in. The width of the strong box girders is 1 ft. 8 in.; the flanges are built up of two ½-inch plates with joint covers, and each riveted to a three-sixteenths web by two angle-irons 3½×3½×nine-sixteenths. In the light box girders the flange plates are ⅝, and the angle-irons 3½×3½×½. The box girders are connected to the under side of bow-strings by twenty 1-inch rivets, and two 1½-inch bolts. A ½ plate is riveted to top flanges of cross girders for attaching road plates according to the third system, Plate 25, Figs. 6 and 8.

Referring to Plate 28, Fig. 5, it will be seen there is an open work facia. This is formed by bolting a ½ plate to ends of cross girders; then filling in the spaces with crosses of 3×½ iron, and attaching, by countersunk screws, to bottom of ½ plates, a line of angle-iron 3×3×⅝. The weight of each bowstring girder is 117 tons; of all the cross girders 180 tons; and of the whole bridge 458 tons. The clear width of this bridge is 56 feet, for the reasons stated in introductory sketch.

The next iron structure in order is the section of Borough Market viaduct from Counter-street to York-street. The bridge over the first street is included. This section of viaduct is 200 feet long, in six spans, and built on a curve. Plate 28 refers to this portion of viaduct, Fig. 1 being a transverse section.

The supporting works are two brick abutments and fifteen cast-iron columns, arranged in sets of three, as shown in Fig. 1. The bearing works are three lines of single web girders, placed immediately over columns, to each of which they are secured by four 1½ tap bolts. These lines of girders are 12 ft. 6 in. apart, centre to centre; they are braced over columns and abutments with plate bracing; at mid span there are open frames. The outer lines of girders are provided with a parapet 6 feet high. The viaduct is covered with 9-inch square timber, with hoop iron tongue 1½×⅛; and on this timber the longitudinal rail timbers are laid.

From the preceding remarks the general features of the viaduct will be understood. The detailed description will, therefore, be commenced with the columns: these are all 24 feet high over all; the diameter at base 2 ft. 1 in., and at capital 1 ft. 9 in.; on plan the capital is 2 ft. 9 in. square; and the thickness of metal in inner columns 1½ inch, and the outer 1 inch.

The base of the inner column is 3 ft. 1 in. square, and has holes to suit four 1½-inch holding-down bolts; the outer columns have a projection on the outer side of base, and the angle filled in with a bracket. There are five holding-down bolts. The foundation for columns consists of—first, a bed of concrete; second, a pier of brickwork in cement, 8 ft. 6 in. high, 8 feet×6 feet at bottom, and 6 feet×4 feet at top—these horizontal dimensions are for the outer columns; third, a 6-inch York landing, the same size as top of brick pier, on which the base of column rests.

It may now be considered that the fifteen columns and the two brick abutments are all in place ready for the bearing works—the inner and outer lines of longitudinal girders.

These girders are all of the single web type, 3 feet high, and are seen in section in Fig. 1; the inner girders for the four centre spans are 32 ft. 3⅝ in. long; the top and bottom flanges are 16 inches wide, and built up of two seven-sixteenths plates, with joint covers; the webs are ½ thick, connected to each flange by two angle-irons 4×4×½, and stiffened at vertical joints by T iron, 5×2½×⅝.

The outer girders on the convex side of viaduct are, for the four centre spans, 32 ft. 5⅞ in. long, and 3 feet high;. each flange is 16 inches wide, ⅝ thick, and connected to a ½ web by two angle-irons, 4×4×⅝; the vertical joints of webs are stiffened the same as inner girders. On the upper side of top flange an angle-iron 3×3×⅝, is riveted. This is for attaching a sheet-iron parapet, similar to that described for Vine-street bridge.

The connexion of longitudinal girders to each other, to bracing and to column, is as follows:—To the bottom flanges of the two girders are flush riveted two ¾-plates, together being the size of top of column, the joint coinciding with webs, and each having two holes for the 1½ inch top bolts, shown in Fig. 4. The top flanges are connected by nine-sixteenths joint-plate; the webs of inner girders are connected by the plate bracing riveted on each side of them; those of outer by the bracing on one side, and a T iron on the other.

The bracing over columns consists of web, angle-iron, and central vertical T irons; the webs are ½, angle-iron 3×3×½, and T iron 5×2½×⅝. The open frames are of T iron, 5×3×½, with diagonal bars of 3½×½; the vertical T irons same section as in plate bracing. The timbers are bolted down by ⅞ hook bolts. The ends of the longitudinal girders, on brick abutments, have riveted to them bearing plates, 3 feet×2 feet×¾ inch. The weight of cast-iron in the viaduct is 54 tons, and the weight of wrought-iron 82 tons 4 cwt.

The section of Borough Market viaduct, from York-street to Wellington-street, is in three spans of 45 feet each; the supporting members are two brick abutments, and two piers of cast-iron columns; there are five columns in one pier, and four in the other, which are the same as those in the other section of viaduct. On plan, this section is of a "fan" shape, being 37 feet wide at one end, and 62 ft. 6 in. at the other; this width is due, as before noticed, to the viaduct being the site of the Eastern Junction of City Extension. Each row of columns is surmounted by a box girder, 2 feet wide and 1 ft. 6 in. deep, which forms the bed for the longitudinal girders, and is riveted thereto; tap bolts secure the box girders to top of columns.

There are in all 24 longitudinal girders, arranged thus: in the opening next York-street, 9; in the centre opening, 8; and in the one next Wellington-street, 7. These girders are all 4 feet deep, and, with the exception of the two face ones in each opening, are all placed parallel with each other. Each of these face girders splay more or less with the inner one of the same opening next it; and in four cases cross girders are filled in between them, for that portion of length in which the distance centre to centre exceeds 4 feet. The distance centre to centre of the cross girders is 4 feet. On the top of the longitudinal girders 6-inch plank is laid; it is transverse to these girders, excepting at those points where the cross girders are introduced.

Five of the girders in the opening next York-street are 51 feet span; the flanges of these are 16 inches wide, and built up of two ½-inch plates, with joint covers; the webs are ½ thick, and connected to flanges by angle-iron, 4×4×⅝. Seventeen of the girders have flanges 16 inches wide by ¾ inch thick, also connected to a ½ web by 4×4×⅝ angle-iron. For the remaining two, the flanges are 16×⅝, and the angle-iron 3×3×⅝: in all cases the webs being in about 5 feet sections. The longest cross girder is 19 feet; it is 16 inches deep, and consists of a ½ web, with two angle-irons 3×3×½, top and bottom for flanges. The shortest cross girder is 6 feet; it is 12 inches deep, with flanges of 2½×2½×½ angle-iron. The bracing, the connection of top flanges of girders, and parapet, are all similar to those in the other section of viaduct. The weight of columns is 40 tons; of the two box girders, 11 tons 2 cwt.; of the longitudinal girder, 129 tons 18 cwt.; and of the whole viaduct, 201 tons.

With reference to St. Thomas's viaduct, it is only necessary to say that the girders mentioned in the introductory sketch vary in length from 41 ft. 4 in. to 19 ft. 8 in. for one opening; and from 48 feet to 25 feet for the other. They are of the single web type, 2 ft. 6 in. deep, braced together by diagonal bars 3×⅝, and covered with 8 inch planking. The weight is 28 tons.

The only bridge remaining to be described is that over the incline to the South-Eastern station. In this the bearing works are two elliptical box-girders, 207 feet and 176 feet long respectively. Plate 28, Fig. 7, is a centre section of the 207 feet girder. The platform of bridge is formed by eighty cross girders, with road plating on the third system. Plate 25, Figs. 6 and 8. Of these eighty girders, thirty-one only are connected to both mains. The longest of these is 50 ft. 4 in., and the shortest 44 feet; the depths of cross girders vary from 1 ft. 6 in. to 9 inches. These will be referred to again.

Returning to the main girders, it is proposed to describe fully the 207 feet girder, and then to point out wherein the 176 feet differs from it.

Since the order in which any structure is built is the best to describe it in, it will be followed in this case. The bottom table is 3 feet wide, and is built up of one nine-sixteenths inch and four full ½-inch plates. These plates are riveted to each other and to four lines of angle-irons, 6×6×1, by five longitudinal lines of rivets 1 inch diameter.

The angle-irons are in pairs, back to back, the space between the vertical arms being such as to admit the web plate, with a ¾-inch side plate on each side of it (the web); the side plates are 18 inches deep, and all the rivets through them are 1 inch diameter.

The distance between webs at centre of girder is 1 ft. 10 in. They are 3 feet widths, and, with the exception of the three at either end, are in two sections vertically, the joint being made by two horizontal strips 6×⅝. The three webs at either end of a line are ½-inch; the next five at either end, ⅝; and the intermediate ones ½. Extra webs, ½-inch thick, are added at either end of each line, for a distance of 15 feet.

The vertical joints of webs are connected by a tee iron, 6×3×⅝, and a strip, 6×⅝—the tee iron external. Both are made to set over side plates and angle iron. The girder is braced internally by eleven diaphragms about 18 feet apart. They are formed of ½ plate and 3×3×½ angle, and are seen in section, and in position in Plate 28, Fig, 7.

The partially built girder may now be supposed standing with bottom table and webs in position, ready for receiving the top table, which is similar in section to the bottom. This is done as follows:—Into the space which the cranked ends of vertical tee irons and strips form with the web, the side plates, 1 ft. 6 in. deep × ¾ thick, are introduced; then into the space which the side plates make with the shorter crank, the longitudinal angle-irons, 6×6×1, are placed. This done, the girder is ready for receiving the top laminated plates; these are 3 ft. wide, six in number, and full ½ in. thick. All the rivets in top table, from lower edge of side plates upward, are 1 in. diameter; the rivets through vertical strips are ⅞ in. diameter. The pitch of rivets throughout is 4 in. Under one end of the girder, twelve rollers 6 in. diameter are placed, with bearing plates and bed plate of cast iron 3 in. thick. The ordinary length of the angle-iron bars is 18 ft.; the joint covers for bottom table are 4 ft., and those for the top table 2 ft. long. The side plates are in 9 ft. lengths, and the joint plates for them are 2 ft. 6 in.×1 ft. Since the distance centre to centre vertical tee irons is 3 ft., and their width 6 in., it will be seen that these joint plates just fit in between the tee irons. The ordinary length of the laminated plates is 6 ft. 8 in. The 176 ft. girder being so similar to the one just described, it is considered only necessary to give the dimensions of those elements which differ. These are as follows: the laminated portion of the top table is built up of five ⅝ plates, and of the bottom of four ½-in. plates. The side plates are ½-in. thick, and in 15-ft. lengths.

As previously stated, more particulars will now be given of the cross girders. There are seven different sections; the dimensions of the strongest are: Depth, 18 in.; flanges, 12 in. wide, built up of two ⅝ plates, with joint plate; web, ½ in.; angle-iron, 5×4×⅝. The dimensions of the lightest are: Depth, 9 in.; web, ½ in., with flanges, each formed of two angle-irons, 4×3½×⅝.

All the cross girders above 9 in. in depth are reduced to that depth, at those ends which are bolted to main girders; and a cast-iron cornice is bolted to them, similar to that shown in Plate 25, Fig. 6.

The cross girders in this case are bolted to main girders; the girders, 12 in. wide, are each connected to the 207-ft. girder with fourteen bolts 1 in. diameter, and to the 176-ft. by thirteen; in all the other cases there are ten. These bolts are long enough to pass through both flanges, the head of bolt bearing against bottom flange or plate riveted thereto. The curve of line on this bridge is to about a ten chain radius. The longitudinal timbers for higher rail are two 12×9 bolted together, and for the lower rail two 12×6. The line is also on a gradient, the difference of level between the ends of the 207-ft. girder being 12 in. The weights are:

207-ft. girder	191	tons	17	cwt.
176-ft. „	134	„	12	„
Heaviest cross girder	5	„	15	„
All „	267	„	10	„
Whole bridge	617	„	17	„

In conclusion, it is only thought necessary to say that in all cases the "rolling load" was taken at 1¼ tons per foot forward of single line; maximum strains in compression and extension, 4 tons and 5 tons respectively per square inch.

The deflections of the various bridges, as on diagram, are produced by a load of one ton per foot run of single line.

The engineer for the line was Mr. J. Hawkshaw, and the whole of the ironwork was executed by Messrs. Cochrane, Grove, and Co., of Dudley.

SOUTHWARK ST. BRIDGE.

Fig. 1.

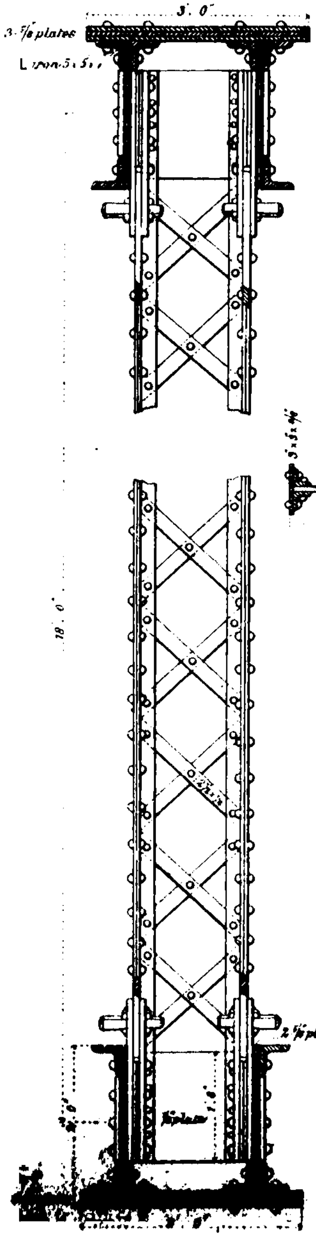
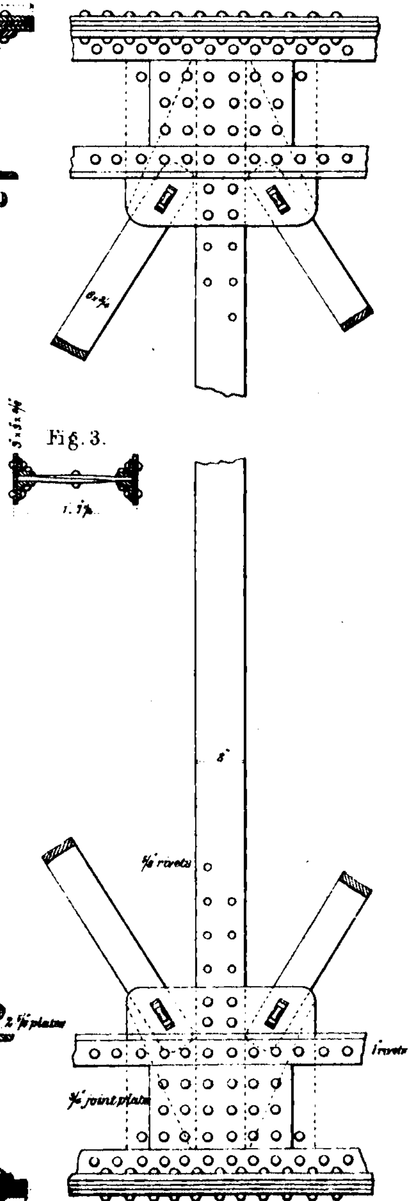


Fig. 2.

Fig. 3.



CLARK'S PERMANENT WAY.

Fig. 1.

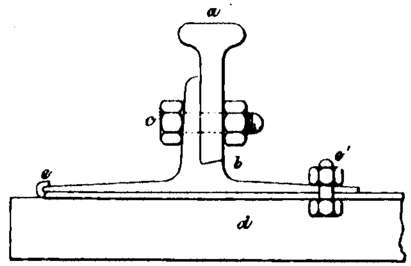


Fig. 2

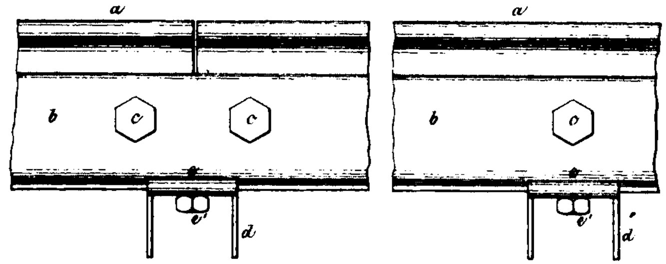


Fig. 4.

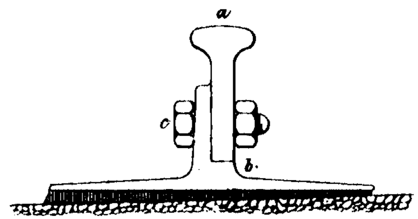


Fig. 5.

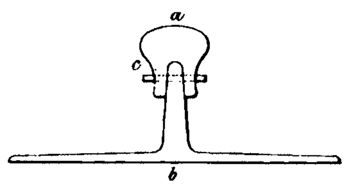
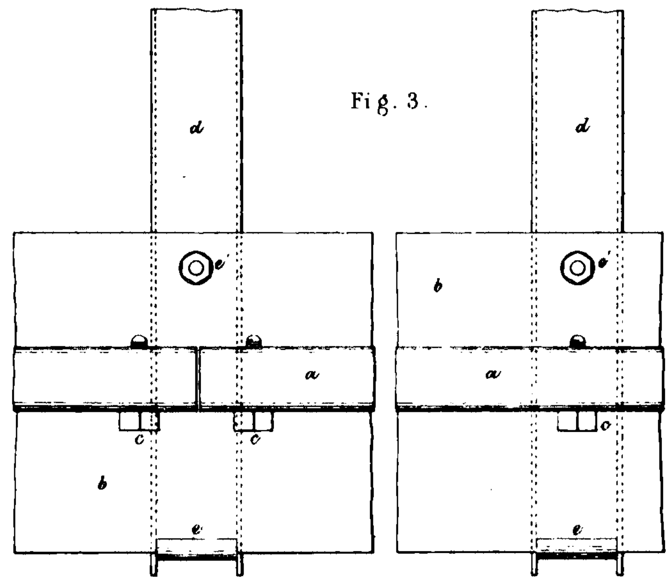


Fig. 3.



J.R. Jobbins

CHARING-CROSS RAILWAY.

Road-bridges—Deflections of Wrought Iron Girders.

NAME OF BRIDGE.	Length of Girders in Clear.		Width of Bridge.		Lines of Way.	Distributed Load in Tons.	Deflections at Centre.
	ft.	in.	ft.	in.	No.	tons.	in.
Joiner-st. bridge ... Main girder	60	0	...		...	108	.66
,, ,, .. ,,	44	0	45	0	3	78	
Approach bridge ... ,,	185	0	...		...	255	.84
,, ,, ... ,,	156	0	43	0	3	210	.63
Wellington-street bridge .... ,,	118	0	...		...	156	.78
,, ,, ... ,,	118	0	36	6	3	156	.72
Borough-market viaduct.........Longl. girds.	46	3	...		...	23	.24
	47	6	38	0	3	23	.24
	46	4	...		...	23	.18
York-st. bridge... ,,	36	0	25	0	2	18	.30
Borough-market viaduct .... ,,	31	6	...		...	20	.24
	32	0	...		...	21	.24
	32	0	25	0	2	21	.30
	32	0	...		...	21	.36
	32	0	...		..	21	.30
	40	0	...		...	26	.42
Southwark-st. bridge . Main gird.	130	0	...		...	220	.42
,, ,, ,,	130	0	56	0	4	This girder not tested.	
Southwark-rd. bridge... ,,	121	0	...		...	172	.54
,, ,, ,,	78	0	35	8	3	110	.36
Blackfriars-rd. bridge... ,,	100	0	...		...	150	.60
,, ,, ,,	100	0	35	8	3	150	.48
Broadwall bridge...Longl. girds.	41	0	35	8	3	20	.24
Waterloo branch bridge .... Main gird.	76	0	...		...	55	.36
,, ,, ... ,,	76	0	26	6	1	21	.18
John-street bridge ... ,,	75	0	...		...	60	.24
,, ,, ... ,,	72	0	35	8	3	55	.24
Waterloo-rd. bridge . ,,	110	0	...		...	150	.48
,, ,, ... ,,	110	0	41	0	3	150	.36
Vine-street bridge..Longl. girds.	48	0	35	8	3	24	.30
York-road bridge ... Main girds.	70	0	...		...	100	.48
,, ,, ... ,,	70	0	35	8	3	100	.48
Sutton-street bridge. ,,	90	0	...		...	135	.36
,, ,, ... ,,	90	0	35	8	...	135	.36
Belvedere-rd. bridge. Longl. gird.	46	0	35	8	3	23	.24

It having been remarked that the chief feature of the Charing-cross Railway was the Hungerford Bridge, the writer proposes to furnish some further particulars of it. His object in keeping simply to the road bridges was to avoid repeating a quantity of information already published. The writer refers to the comprehensive paper by Mr. Harrison Hayter, C.E., read before the Institution of Civil Engineers, April 28, 1863.* He would now confine his attention chiefly to a minute description of the main girders of the 154 feet spans, and the method of suspending the cross girders thereto.

The main girders just referred to, may be described as wrought-iron lattice girders. They each consist of a top and bottom horizontal member, 4 ft. and 3 ft. wide respectively, two vertical end pillars, and two systems of diagonal struts and ties, the whole being connected together with pins of puddled steel. One of the systems of struts and ties forms with the lower horizontal member a series of seven triangles, and the other system does the same with the top member. It will thus be seen there are fifteen pins in each member, the length of girder over all at top being 164 feet. The distance between centre to centre of pin holes at bottom is 10 ft. $11\frac{9}{16}$ in., thus making the distance between centre to centre end pin holes 153 ft. $9\frac{5}{8}$ in., the length of bottom over all being 163 ft. $9\frac{3}{8}$ in. The struts and ties being all one length centre to centre of pin holes, and the distance between centres of pin holes of bottom being, as stated, $\frac{9}{16}$ths of an inch less than those at top, produces a camber of 4 in. at centre of girder. The depths of girder are:—total depth at centre 14 ft. $4\frac{3}{8}$ in.; depth between centres of gravity of top and bottom 13 ft.; centre to centre pin holes 11 ft. 6 in. The top and bottom members each consist of a horizontal table and four vertical ribs; these ribs are bored to receive the puddled steel pins. The sizes of the upper and lower pins are the same, and of the following dimensions: the two end 7 in. diameter; the next two at either end $6\frac{1}{2}$ in.; the next two at either end 6 in.; and the five central ones 5 in. diameter. It is proposed now to describe the construction of each member. The horizontal table of the bottom is 3 feet wide, and built up of 160 plates. There are six layers, a centre one $\frac{11}{16}$ and five $\frac{1}{2}$, reduced to two at ends, one $\frac{11}{16}$ and one $\frac{1}{2}$.

Each layer of plate is in two widths; the upper one in two 18-in. widths, and the remainder in 12 in. and 24 in., so that they break joint transversely. The length of overlap in a longitudinal direction is 16 in. The ordinary length of the plates is 7 ft. 11·88 in. These plates are all riveted to one another and to four lines of angle-iron, by six rows of 1 in. rivets. The angle-irons, which are 6 by 6 by 1 in. at centre, reduced to 6 by 6 by $\frac{3}{4}$ at ends, are all placed with the horizontal arms inwards, or towards the centre of the girder. The holes are so arranged that between the backs of the two outside lines of angle and the edge of the horizontal table, there is a ledge $1\frac{1}{2}$ wide at centre of girder. This is to admit of the vertical ribs being flush with the edges of the horizontal table. The two central lines of rivet holes are so arranged that the distance between the two inside vertical ribs is 13 in. The angle covers are 4 ft. long, 5 by 5 in. by 37 lb. per foot.

To the four lines of angle-iron the vertical ribs are riveted with $\frac{7}{8}$ rivets. The two outside ribs are 24 in. deep, and each consist of a $\frac{5}{8}$ in. and $\frac{1}{2}$ in. plate at centre, reduced to two $\frac{5}{8}$ in. at ends. The ordinary length of these plates is 10 ft. $11\frac{11}{16}$ in., and they break joint at the pin holes. The joint plates are 2 ft. 4 in. long, the outer one 24 in., and the inner 18 in. deep, the thickness is 1 in., so as to give a good bearing surface for the pins. The two inner ribs are 21 in. deep, and each consist of two $\frac{5}{8}$ plates at centre, reduced to $\frac{3}{8}$ at ends. In addition to these an extra length of plate, 15 in. deep by $\frac{1}{2}$ in. thick, extends sufficiently to contain the five 5 in. pin holes; this plating is on the inner side of the ribs. The lengths of plates, sizes of joint plates, &c., are similar to those for the outer ribs, excepting the difference due to the lesser depth. From what has been said it will be seen that the horizontal table with the four vertical ribs form three troughs, the two side troughs being occupied by the struts and ties.

The horizontal table of the top member is 4 ft. wide, built up of 182 plates, all $\frac{1}{2}$ thick. There are five layers of plates at centre of girder, reduced to two at ends; these layers, like those for bottom are in two widths; the lower layer is in two equal widths of 2 ft., and the remainder are 1 ft. 5 in. and 2 ft. 7 in., thus breaking joint transversely. The ordinary length of the plates is 6 ft. 8 in., and the overlap in a longitudinal direction 16 in. This horizontal table is riveted together and to four lines of angle-iron by six rows of 1-in. rivets: these angle-irons are placed with the horizontal arm towards the edge of the table. The ordinary length of a bar is 11 ft., and of an angle cover 2 ft.; in other respects they are similar to those in bottom. The holes are so arranged that the distance between the backs of the exterior angle-irons is 2 ft. $10\frac{1}{2}$ in., and between the backs of the interior 1 ft. 2 in.

The plates composing the vertical ribs are in 11 ft. lengths; the joint plates, mode of breaking joint, and depths of plates, being similar to the bottom. Each of the outer and inner ribs consists of two $\frac{1}{2}$ plates at centre, reduced to two $\frac{3}{8}$ at ends.

The end pillars will now be described. These are 13 ft. $9\frac{1}{2}$ in. high, 5 ft. $2\frac{3}{4}$ in. long, 2 ft. $10\frac{1}{2}$ in. wide at bottom, and 2 ft. 9 in. at top; the sides, back, and front, are all of $\frac{3}{8}$ boiler plate; internally the pillar is divided into three compartments, by diaphragms $\frac{1}{2}$ in. thick. Each side is in two sections vertically, and three sections horizontally; the vertical joints are covered externally by strips, 6 by $\frac{3}{8}$, and internally by T iron, 5 by 3 by $\frac{1}{2}$, to which the $\frac{1}{2}$ diaphragms are riveted. The front and back are connected to the sides by angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$. The end pillars are riveted together with $\frac{7}{8}$-rivets.

Diagonal struts and ties: Each strut consists of two links in one solid forging; these links are bored at each end to suit the pins, and are united firmly together by zig-zag bracing of bar iron, $4\frac{1}{2}$ by $\frac{3}{8}$, four cast-iron distance tubes, and four bolts, $1\frac{1}{2}$ in. diameter; the bolts, of course, pass through the distance tubes, and when screwed tightly up, make each strut a rigid framework. The links composing a strut are 12 in. by 3 in. at the ends of the girder, and 6 in. by $2\frac{1}{2}$ in. at the centre.

The diagonal ties, like the struts, each consist of a pair of links, and each link consists of two or three separate links riveted together; these links are Howard's suspension links. Each link of a tie is 12 in. by $2\frac{1}{2}$ in. at ends of girder, and 6 in. by 2 in. at centre. In consequence of the central diagonals having to act as both struts and ties, the two pairs meeting at the lower central 5-in. pin are constructed similarly to the struts. The diagonals are all bolted together at their intersections; the bolts are 1 in. diameter, with ornamental nuts of cast-iron. The ties and struts were all sent to the works, bored to the finished size; but the plates composing the vertical ribs were sent bored out half an inch less than the finished size. The riveting being completed, with the exception of fourteen holes at each pin-hole joint, the vertical ribs were then bored out by means of a boring bar, fitted with two cutters, and working in two cast-iron bearings, bolted to the outer vertical ribs with four bolts. It was for this purpose four of the holes in each pin joint were left open, the remaining ten are for the angle-irons, for attaching cross girders. The boring bar was driven through a counter shaft by a small steam-engine, fitted with small flanged wheels, which run on the exterior vertical bottom ribs; by this means the engine could be moved to any part of the girder with facility. The pins were driven home with a ram, which consisted of a pin in its rough state, fitted with the necessary appliances for working it.

The pins were made long enough to project about $1\frac{1}{2}$ in. beyond the

* See *C. E. & A. Journal*, vol. 27 (1864), p. 219, 267, 300.

outer vertical ribs on either side of girder. This is to accommodate the vertical links, which thus divide the girder into fourteen nearly rectangular spaces, as seen in side elevation. The links are 7 in. by 1 in. at ends of girder, reduced to 6 in. by 1 in. at centre. In both top and bottom straps of 3 in. by ¾ in. iron were riveted to both the inner and outer vertical ribs; there are two of these straps between any two pins.

Cross girders: These are on the lattice principle, 54 ft. long, 4 ft. deep at centre, and 2 ft. 1½ in. at ends; they consist of a top and bottom flange, each 18 in. wide and in two ⅜ thicknesses, united together by lattice bars and angle-irons. Two lines of angle-iron are riveted to each flange, back to back, and 1 in. apart. The lattice bars, sloping one way on either side of centre, are 1 in., and the others ⅜ in. thick; they vary in width, from 4 in. at the centre to 6 in. at the ends. The 1 in. lattice bars are riveted between the angle-iron and the ⅜ in. external to them. At each end of the cross girder a lattice cantilever is riveted, it is 7 ft. 3 in. long, 2 ft. 1½ in. deep, where it joins the cross girder tapering to 1 ft. 2 in. at the ends; each flange consists of two angle-irons, 3½ by 3½ by ⅜, united together by lattice bars, 2 by ⅝ and 2 by ⅜, similarly to the cross girders. At the sides of the footpaths is a cast-iron railing, and the ends of the cantilevers are screened by a cast-iron cornice. The deflection of a cross girder with a load of 70 tons was 1 in., and the permanent set ¼ in.

Method of attaching cross to main girders: To either side of bottom of main girders, and on either side of the pin holes, an angle-iron 4 by 4 by ⅝ is riveted; these angle-irons extend 2 ft. 6 in. below the under-side of girder in the case of the inner, the outer being 4 in. less. From what has been said, it will be seen there are four angle-irons at each pin. The cross girder fits between these angle-irons, similar to the axle box in the horn plates of a railway carriage. To secure the cross girders to these angle-irons, a wrought-iron plate 5 ft. 7 in. long, and ¼ in. thick, is attached to each end and on both sides, by means of reverse angle-irons on top and bottom flanges. Each angle-iron is secured to the main girders with five rivets, and to the cross girder with seven and six, in the case of the inner and outer respectively.

Each main girder is designed to support a maximum distributed load of 750 tons; this weight produces a strain in the upper and lower members of 1111 tons which is resisted by 276·5 square inches of section, and 211·75 square inches respectively.

Remarks on the distribution of metal in one of the main trusses (154 ft. span), the maximum load and central strain on truss due to it, and the pressure on foundations:—

Distribution of metal in one main truss:

	Tons	cwt.	qrs.
Top chord	70	4	2
Bottom do	67	15	2
End pillars	6	0	0
Bracing	46	0	0
Total ...	190	0	0

Rolling load on one main girder, obtained thus: (N.B. rolling load 1½ tons per foot of single line)

	Tons.
Rolling load 156 ft. by 2½ tons	390
Main truss, deducting end pillars...	184
Cross girders and cantilevers	67
Rails	7
Timber in planking and longitudinals	41
Load on footpath taken at 120 lb. per ft. sup. ...	58

The above load is exclusive of cornice, hand-rail, fish plates, bolts, spikes, and chairs for rails, hoop-iron tongue, and bolts for planking.

Pressure on foundation:

From Trinity high-water mark to underside main trusses is 29 ft., which added to the rise of tide, 17½ ft. (say 18 ft.), gives 47 ft. Since brickwork weighs 1 cwt. per foot cube, we have a pressure on top of cone, due to brickwork only, of 2 tons 7 cwt. per sup. foot.

First take the load on main truss, including its own weight as 750 tons, and the diameter of the brick cylinder at 9 ft. 9 in., thus:—

	Tons	cwt.
$\frac{\text{Load 750 tons}}{\text{Area 9 ft. 9 in.} = 74\cdot66 \text{ sq. ft.}}$ = ...	10	0
Pressure due to brickwork...	2	7
Total pressure per sq. ft. at top of cone	12	7

Taking cylinders at 10 ft. diameter:

	Tons	cwt.
$\frac{\text{Load 750 tons}}{\text{Area 10 ft. dia. } 78\cdot54}$ = ...	9	11
Pressure from brickwork	2	7
Total pressure per sq. ft. on top of cone	11	18

Central strain on one main truss, 154 ft. span, with a maximum distributed load of 750 tons, including its own weight.

Assuming the distance between the centres of gravity of the upper and lower chords to be 13 ft. (which was the result of calculations made by Mr. Parkes), the central strain on one main truss will be 1·111 tons. This number divided by 4 or 5, will give the required sectional areas of top and bottom chords respectively, as follows:

	Sq. in.
$\frac{1\cdot111}{4}$ = required section of top = ...	277·7
Actual section = ...	276·5
Deficiency	1·2
	Sq. in.
$\frac{1\cdot111}{5}$ = required section of bottom = ...	222·2
Actual section	211·75
Deficiency	10·45

	£	s.	d.
There are 16,052 rivets in each 154 ft. truss.			
The cost of the whole bridge ..	180,000	0	0
„ per square foot	1	15	0
„ per lineal foot	131	0	0

The cylinder for the 154-ft. spans cost £20 per foot lineal; the outer and inner cylinders for the fan end, £12 and £10 respectively.

One of the cylinders for the 154-ft. spans sunk permanently 4 in. with 700 tons, and one 3 inches with 450 tons

Table of Dimensions, &c.

	Top Flange.	Bottom Flange.	Span.	Depth.	$\frac{L}{8d}$	Load.	Strain at Centre.	Weights. Total.	Weights. Main Gird.
	sq. in.	sq. in.	ft. in.	ft. in.		tons	tons.	tons.	tons.
Broadwall ...	22.87	18.15	41 0	2 6	2.05	31	63¼	43	4¼
York-road ...	65.6	51.05	74 0	7 3	1.28	202	258¼	141¾	25
John-street ...	57.35	47.35	88 1	6 9	1.63	124	202	124½	24½
Waterloo Branch......	61.85	51.05	77 9	6 3	1.55	146	226¼	94	24½
Wellington-st.	104.8	81.5	124 3	11 8	1.33	328	436	248	65
Joiner-street. .	82.0	67.6	61 3	5 2	1.48	202	299	115¾	21½
Sutton-street .	80.9	64.55	103 3	7 5	1.75	195	341¼	178¼	45¾
Waterloo Main	103.4	85.4	111 9	11 4	1.28	332	408¼	276¾	62¼
Blackfriars-rd	93.2	77.0	100 9	10 3	1.28	303	372½	214¾	53
Southwark-rd. 135 ft.	103.4	85.4	125 9	11 8	1.34	299	400	199 (135 ft. and 82 ft.)	68¼
„ 82 ft.	63.75	52.05	...	8 8	...	...	...		27¾
Southwark-st.	159.0	134.0	140 0	18 9	.93	555	516	458	117
Approach 207 ft.	188.0	138.0	195 0	18 2	1.34 (207 ft. and 176 ft.)	642	860¼	618 (207 ft. and 176 ft.)	192
„ 176 ft.	134.0	109.0	...	18 2		664	890		184¾

Discussion.

Mr. CARRINGTON said, great praise was due to Mr. Parkes for the time and attention he had given to his really valuable paper. The paper was an excellent record of the wrought-iron bridges executed on the Charing-cross Railway. It appeared curious, in looking at all these bridges, that there should be so many different designs. Of course a small span required a different design to a large span, but it certainly did not appear to be correct to have bow-string girders for a span smaller than for plate girders. If an open webbed girder was good and proper for a given span, most certainly an open webbed girder was better for a larger span than a plate girder, or close webbed girder. Over the new street in the Borough, the bow-string bridge seemed nearly the proper thing, for the span was large, and required an open webbed girder, both for appearance and economy. All spans over 80 ft. required open webs; they were less costly, and certainly had a much lighter appearance than close webbed plate girders. Yet, strange as it might appear, an ugly plate girder was adopted over the approach to London-bridge station, and over a span larger than for the bow-string. Why this was, he could not understand. From what he remembered, there were six distinct species of girders in those bridges.

1. The single webbed plate girder.
2. The double webbed, or box plate girder.
3. The bow-string girder.
4. The bow-string made into a box bow-string plate girder by having a double web instead of struts and ties.
5. The main girders of the Thames bridge.
6. The cross girders of ditto, which were lattice girders.

Why there should be so many kinds of girders, he could not quite understand, for they did not appear to be arranged in all cases according to the spans of the bridges. That was, plate girders appeared to be put where lattice or open web girders ought to be.

The pitch, or distance from centre to centre, of cross girders in the Thames bridge was 11 ft., and the pitch of cross girders on the other bridges varied from 3 ft. to 4 ft. Why there should be that great difference in pitch was not at all clear. It would appear that the distance from centre to centre of the driving wheels of the locomotive would have something to do with deciding the pitch of the cross girders. Suppose 7 ft. to be about the distance apart of the driving wheels, then 5 ft. or 6 ft. would apparently be more nearly the correct distance (and therefore the most economical) of the cross girders. If the distance was greater than 6 ft., it was advisable to put in wrought-iron longitudinal bearers under each rail, so as to complete the proper framework of the bridge in iron. The new railway bridge at Blackfriars was a good specimen of framing for the roadway of a bridge. In the roadway of the Charing-cross bridge, there were longitudinal timbers 15 by 15 in. under each rail, and those timbers had to carry a distance of 11 ft. It certainly appeared more advisable to put a light wrought-iron girder in the place of those timbers, so as to make a complete iron bridge, and not one partly of iron and partly of wood. If in making a railway generally, one or more bridges of 11 ft. or 12 ft. span occurred it would not be advisable to carry over on balks of timber; either wrought or cast-iron girders would be used, or an arch. Therefore, why should timber be used for 11 ft. spans on such a line as the Charing-cross Railway?

It was a waste of material to put the cross girders too close together. No matter how near together or how far apart up to about 6 ft., the cross girders must be the same strength, for each one must be calculated to carry the driving wheels of a locomotive, and up to 6 ft. apart, a greater load could not be put on; therefore, if cross girders were only 3 ft. apart, there were twice as many as necessary, and this useless addition added to the weight of the bridge, not only in themselves, but also in increasing the weight of metal in the main girders to carry that extra load.

Much has been said as to the danger of the cross girders leaving the main girders when suspended from the under-side of the bottom flange. That method of fixing did not appear, at the first glance, to be proportionately strong to the strength of the girders; but a little calculation would show that such a connection is not always the weakest part. Taking a cross girder on the Thames bridge, at the junction with the under-side of the main girder, there were four vertical angle-irons, each angle-iron laying hold of the cross girder with about seven rivets, ⅞ diameter, making a total of twenty-eight rivets, each 6 in. in sectional area, giving a total shearing area of 16·8 square inches. Two of these cross girders were tested with a load of 140 tons, equal to 70 tons on each girder, equal to 35 tons at each end, tending to shear the 16·8 square inches of rivets. That would give a little over 2 tons per square inch shearing strain on the rivets, which must be allowed to be ample for safety. Still cross girders, as a rule, do not look well when suspended from the under-side of the main girders, and whenever it is possible, they ought to rest on the bottom flange close to the web. If such arrangement had been adopted on these bridges, there would have been no necessity to cover the ends with a heavy cast-iron cornice, which only added to the weight and expense of the bridge.

There was no doubt that drilled holes in wrought-iron plates decreased the strength of the metal less than punched holes; the metal on the circumference of the holes must certainly be much less injured, and therefore leave more strength in the plate. It was more expensive to drill holes than to punch them; but if by drilling, say ten per cent. of the strength of the remaining metal was saved, was it not worth the extra cost of drilling?

If the punching was badly done the metal was injured considerably, but in order to insure the least possible injury to the metal by punching, the punch must fit the die fairly, and the edges of both must be sharp and clean, which was not always the case; great care ought to be taken to insure clean sharp edges to the punch and die. Such attention was but seldom given, and the result was that in many cases the holes were half punched and half drifted, much to the injury of the remaining metal in the bar.

There could be no doubt that if the top flange plates were curved transversely they were in a much better form for resisting compression, but the curving of the plates added to the expense of making; it was, therefore, cheaper to add angle-irons on the outside edge, so as to give it a good form for compression. That did equally as well, or better, than curving the top plate, was very cheap, for no extra metal was required, and gave a capital form for compression.

In curving longitudinally the top flanges of wrought-iron girders, the expense of the manufacture was increased and but little metal saved; it was, therefore, generally cheaper to keep the two flanges parallel, and avoid adding to the work and difficulty in putting the plates and angle-irons together. He considered that all the bridges were amply strong for the work they had to do, and they were certainly not weak for want of metal.

(To be continued.)

Reviews.

The Applications of Geology to the Arts and Manufactures. By Prof. D. F. Ansted, M.A., F.R.S. London: Robt. Hardwicke, 1865.

In the "Cantor" course of lectures, delivered by Prof. Ansted before the Society of Arts last session, the applications of geology to the arts and manufactures formed an interesting subject. There were six lectures, including agricultural geology, springs and water supply, minerals obtained from superficial and from stratified deposits, and those obtained from mineral veins. These lectures have since been amplified and published in a small volume, that will be found to contain much valuable and interesting matter. We briefly alluded to the book in our last number and we now purpose to give a more extended notice, with extracts of those portions that are more especially interesting to our readers.

The water supply of towns has of late years become a matter of serious consideration, when so many of the streams that were once relied on for furnishing abundance of wholesome water have become contaminated and rendered unfit for drinking in consequence of the improvements in drainage and the operations of Boards of Health, who, by recklessly converting the streams into drains, have rendered it difficult to find a supply of pure water—excepting in places remote from human habitation. Prof. Ansted helps to remove this difficulty, by showing the class of rocks and strata from which supplies of water may be drawn, but these are nevertheless not so abundant but that, with all his knowledge of the water-bearing rocks in the neighbourhood of London, he casts his eye somewhat wistfully to Bala lake, in North Wales, from which it was at one time proposed to supply the Metropolis. The following general statement of facts shows the principles on which any calculations for obtaining a supply of pure water must be founded:—

"All rocks contain water. Even the dryest and most compact marbles in their driest state hold from ·4 to 4 per cent. by weight in their composition. Granites contain water: some even in the ordinary dry state contain one pint and a half of water in every cubic foot, and are capable of absorbing half a pint more. This is independent of the water of consolidation. In every case, under the least favourable conditions, we may assert that none of the rocks commonly met with near the earth's surface, and regarded as non-absorbent or impermeable, contain less than two pints of water in every cubic yard. In other words, as a cubic yard of ordinary stone weighs nearly 2 tons, we may say that each ton even of the least absorbent rock will contain a pint of water. . . .

The quantity of water capable of being held by common loose sea-sand amounts to at least two 2 gallons in a cubic foot. In ordinary sandstones nearly half that quantity would be contained; and in the best building-stones belonging to the sandstone group, from four to five pints of water are contained in each cubic foot of the stone in its ordinary state. It will give a better idea of this quantity to say that, in an area of such sandstone in its ordinary state, occupying ten square miles, and ten yards in thickness, the quantity of water contained is from four to five hundred millions of gallons. This would fill a reservoir of a hundred acres to the depth of ten feet. If, then, there be beneath the surface, at any depth, and between impermeable beds, a space ten miles square of sandstone, ten yards thick, this sandstone would be capable of containing between forty and fifty thousand millions of gallons of water; and if these sands were fed from above by the rain-fall of a district of one hundred square miles, on which the rain-fall was twenty-six inches per annum, of which one-third part entered the earth, it would need three years to accumulate the quantity named. It is evident, then, that the underground store of water must generally be greatly in excess of the mean annual supply. It will be important to remember this in estimating the value of any underground source of springs fed by a drainage area of measurable extent. The underground store, though really dependent on the rain-fall ultimately, is rather dependent on the average than on any particular season. . . .

Limestones differ from sandstones in many ways, independently of their composition; and their water capacity as well as their behaviour as water-bearing rocks are among these points of difference. Thus, the least absorbent of the common limestones of England holds as much water in its ordinary state as a good compact variety of sandstone fit for building purposes—namely, from four to five pints in the cubic foot; while a cubic foot of Bath stone will absorb double that quantity, and some varieties of magnesian limestone nearly three times as much. A bed of such stone in the earth, ten yards thick, would contain in an area of ten miles square as much water as would fill a reservoir of three hundred and fifty acres to a depth of ten feet.

Chalk is still more absorbent than the building limestones, for a cubic foot of soft chalk will hold as much as two gallons of water, or as much as loose sand. Such chalk will take up half its own bulk of water, and yet hardly appear wet. By exhaustive pumping, however, a large quantity of water may be obtained from chalk; for the rock seems to act as a sponge, the water tending to sink to the bottom."

Professor Ansted, having explained generally the conditions of the interior of the earth, under which springs rise naturally or water may be obtained artificially, thus states the practical limits to the supply from springs that are even most favourably circumstanced:

"Chalk, loose sand, and some sandstones, will certainly yield to pumping a large quantity of water, and this will be replaced from time to time by rain, while the quantity of water contained in a given area of such rock, saturated to a certain depth, may very greatly exceed the quantity required for the town or city built on the surface. But it by no means follows that the water is obtainable by wells and borings because it is present in the rock. The loosest varieties of rock are sufficiently close in texture to offer great difficulties to the free passage of water; and even from wells of exhaustion the quantity of water removed in a given time is not only incapable of being increased, whatever the extent of wetness, but the rock is only drained of water within the content of a cone whose base is at the surface and whose apex is the bottom of the well, and the area of whose base is rarely more than half a mile in radius. The two rocks that yield the largest quantity of water are chalk and soft sandstone; and concerning both these experiment has shown that as such rocks commonly exist, and without large open fissures and natural reservoirs; little more than a million gallons per day can be expected from a single well. To yield this maximum, also, such wells must be at least a mile asunder. But even these are the indications of possible results, and could not be calculated upon. It is only in the event of reaching a natural reservoir of large size, existing under pressure in the interior of some limestone rock, that a large permanent supply could be obtained; and such reservoir would in time be exhausted if the removal of the water were in excess of the supply from the surrounding rocks. In the case of deep Artesian springs, where the supply comes from a distance, and represents the rainfall on a large area of outcropping beds, the case is different in some measure; but even then it has always been found that there is a practical limit to the quantity obtainable, and that one well interferes with another if the distance between them is very small. This is the case even when the drainage area is certainly large enough to supply many times over the whole quantity removed."

The finding of an abundant supply of water in the various British rocks that are most familiar is after all mere probability, but the results of geological observations lead to the following conclusions:

"The upper tertiaries of England, including the gravel, rarely afford anything more than land-springs. From the boulder clay, indeed, water is obtained, though not often in large quantity. It is obtained in such cases from under the clays, and therefore, in so far, from outcropping beds below impermeable strata; but the clays are irregular, and no important supply can be expected in this way. It is not till we penetrate the lower tertiaries, and reach the permeable sands between the London clay and the underlying secondary rock, that we obtain large supplies from Artesian borings. The sands within the London clay also contain water, and some springs have been got from them. The supply from the sands below the London clay is extremely large.

Chalk is a rock containing, by absorption, an enormous quantity of water, which is distributed throughout the whole mass, though chiefly abundant in the lower part. The lines of flint favour percolation, and occasional spaces in the interior of the rock exist, and are generally full. At intervals in the chalk there must be beds that hold back water better than the rest, and thus many wells have been successfully sunk only a certain distance into the rock. Though generally permeable, chalk in many places seems to keep back water, especially in the upper part, where the interstices are, perhaps, choked by the fine particles of argillaceous mud washed into them from the London and plastic clays. Water may almost always be obtained by sinking into the chalk to a sufficient depth, though not always in large quantity, or rising high.*

Wells sunk through the chalk into the upper greensand are not always more successful than those terminating in the chalk; but the gault below the upper greensand being quite impermeable, water may generally be expected on reaching this bed. In the gault there is little water; but the lower greensands below are everywhere in England extremely wet. Almost indefinite supplies might be expected therefore from sinking to this rock, but the limitations already made to the quantity obtainable from a single well, or from wells within a given distance of each other, apply here not less clearly than elsewhere. The water of the lower greensand is irony if got near the outcrop of the bed, but when filtered through other beds, especially when passing through much clay, it becomes more pure.

Little water can be got from the beds of clay at the top of the Wealden series, nor is the Hastings sand very much to be depended upon. The Kimmeridge clay and the Oxford clay also are so retentive, and separated by bands of permeable rock of so little importance, as to have little value as water-bearing beds. It must not be supposed, indeed, that water is not to be got between or even amongst these two important bands of clay, but it depends on local conditions, and its presence cannot safely be assumed without proof. The Portland rock above the Kimmeridge clay includes overlying stones and an underlying sand, the former of which hold water chiefly in crevices, but the latter in its mass.

The lower oolites contain much water in various beds, the alternation of clays and open limestones being very frequent. In those parts of England where these rocks come to the surface, the wells are not very deep, but the supply is tolerably constant. In all cases the wells have to be sunk into the limestone to its plane of saturation, wherever that may be, or even through it to the clay, as the rock does not otherwise yield a supply.

The lias holds back water, so that at its contact with the lower oolite there is almost always a line of springs, and under favourable conditions the supply is large and constant. Wells sunk into the upper beds of the lias rarely fail in obtaining water, but the quality is not always very good.

Wells sunk through the lias where the thickness of these clays is not too great, almost invariably obtain water from the new red sandstone. Wells sunk in the new red sandstone are also almost certain of success, to some extent; but, owing to the number of close faults, the quantity cannot be depended on, and the water is apt to be salt. The new red sandstone is eminently a water-bearing bed, and the numerous alternations of marl and sand render it possible lo obtain water from almost all depths. From a well sunk at Gorton, by the Manchester and Salford Waterworks Company, into the new red sandstone, as much as two million gallons per day have been obtained by the aid of radiating galleries from the bottom of the shaft and by exhaustive pumping.

The magnesian limestone is a rock full of cavities, and very cellular. The cavities and cells are filled to a certain level, and water may, therefore, be obtained from this rock. Large quantities of water are present not only in the magnesian limestone, but in the underlying coal-measures and carboniferous limestone. In the coal-measures, at the underclay beneath each seam of coal, and in the limestone in the cavities, wherever there is an impermeable band between strata, or at faults, water is found. The faulted condition of the carboniferous and older rocks in England greatly affects the water capacity of the rock. The old red sandstone is a variable rock, sometimes containing much water in sandy beds, sometimes in cavities, and, at intervals, between the strata. There is generally a good store of water wherever this rock prevails.

In Silurian rocks there are many alternations of permeable and impermeable rocks, and water appears in the intervals. More, however, is to be got from faults and fissures, which are very numerous, than from any strata. The limestones of this period are, for the most part, argillaceous, and, therefore, hold back water; and they are less cracked and fissured than the carboniferous limestone and oolites.

Slates, schists, and all varieties of granite, hold water only in fissures; but from these it may be sought for, in some cases, systematically. Where there is a considerable rainfall, these rocks sometimes afford large supplies, and wells have been sunk into all of them with success. Little dependence can be placed on such rocks, however; for the fissures, though often systematic, and not unfrequently open, do not always communicate readily from one to another."

That portion of the applications of geology to the arts and manufactures which relates to the comparative durability of different stones used in construction and architecture will probably be considered most important, but in treating this branch of the subject Prof. Ansted does little more than record the experience of architects and builders. It is a question, indeed, rather for the chemist than for the geologist to determine. The fact is well-known—and the Houses of Parliament have afforded lamentable confirmation of it—that in the same quarry stone of the same geological formation is very different in its mechanical structure; and it was stated by the late Mr. Smith, one the commissioners appointed to select the stone for that important building, that all their efforts had been marred by the miserable economy of not appointing a responsible and properly qualified person to superintend the works of the quarrymen. We must be content with quoting on the subject of building stones the following observations by Prof. Ansted, respecting magnesian limestones and their various degrees of durability.

"Magnesian limestones occur in various parts of the middle and north-east of England. They may be described as consisting of a variable proportion of carbonate of lime and carbonate of magnesia, and as stones of this composition have been extensively used in some recent important buildings in London, I may be expected to give a more particular notice of them than would otherwise be necessary. The colour of the best of them is a

* I am informed that 6,000,000 gallons of water per day have been obtained, without exhaustive pumping, from a single well in the chalk near the mouth of the Thames.

good light brown, of warm and somewhat irony tint; their density is greater than that of the oolites; the labour on them is intermediate between that on the gritstones and Portland, and they can be obtained of any required size. They are also four times stronger than Portland. Bolsover in Derbyshire, Anston, and other places both in Nottinghamshire and Yorkshire, all in the same district, yield abundantly this kind of stone, which appears to possess every desirable quality, and, indeed, when careful inqu ry was made concerning buildings of great age in the neighbourhood constructed of it, there was every reason to presume that it was a durable material. Under these circumstances it can hardly excite wonder that the commissioners for selecting stone for the New Houses of Parliament agreed to recommend it. It was used for that building, and for some others in London constructed about the same time, and among these was the Museum of Economic Geology, in Jermyn Street. The stone in the latter building is extremely good. With regard to the former, it is well known how great a failure has resulted, Whether this has arisen from want of care in selecting the stone, from the more trying exposure, or from the quarry ultimately selected not yielding such good quality of stone as the specimens examined, it is now too late to discuss, but the result should be a warning not to trust to local indications, and not to risk a building of importance to an experimental material, or one of which so little was known in the exact kind of exposure to which it was to be subjected.

The best varieties of magnesian limestone are those in which there is at least forty per cent. of carbonate of magnesia and four or five per cent. of silica. But the composition alone is of comparatively small importance, for there is no doubt that the state of crystallization is the point of chief importance. Where this is complete the stone resists attack, but it is an unfortunate peculiarity of the admixtures of carbonates of lime with carbonates of magnesia that they are rarely the same for many yards together, even in the same quarry. It is not likely that these stones, which at one time enjoyed a high reputation, will again be favourably regarded in the London market, nor is it fit that they should be so."

On Letters Patent for Inventions. By Frederick Edwards, jun. London: Robt. Hardwicke. 1865.

The author of this work has endeavoured to analyse the working of the present patent laws, and what has been their productive result since the change in the law took place in 1852. Upon the subject he says:—

"Every one who remembers the passing of the Patent Law Amendment Act of 1852, must be aware what reasonable expectations were formed from removing the old complex and expensive machinery, and substituting one that would give instant protection to the inventor, and that, if he should be unsuccessful, might occasion him but inconsiderable loss. And if, on carefully considering the various results of twelve years' working of the Act, he is obliged to see that those results are very different to what he could have expected, and that even the most experienced had been deceived.

We perfectly agree with him as to the deception, and have never been able to see why the old law might not have been simply altered to achieve more beneficial results than the present; it merely required the doing away with caveats, the giving protection from the date of application, making the grant to the inventor embrace the United Kingdom, and lessening the fees, we think some £60 for the fourteen years sufficient and more than sufficient to pay the Government, and this sum might have been paid, say £5 on the application, and £15 on receiving the grant, in which the patentee might by a proviso contained therein be allowed to drop his patent right, if he desired, at the end of eighteen months upon finding it unproductive; but if he did not wish it to cease, the remaining portion of fees, £40, to be then paid. The whole of the printing and publishing of specifications under the present act, we look upon as doing no other good than putting money into the paper maker's, the printer's and the lithographer's pockets. The portion of the work where the rights of authors and inventors are considered we cannot agree with; in our opinion both the author and inventor are justly entitled to whatever reward their imagination and skill may produce, without any interference of Government. The law is strong enough to prevent a man being robbed of anything he may be possessed of by purchase, and why should it not be equally so to protect the labors of the author and inventor. Very simple and inexpensive means by way of legislation might do this.

The number of patents that was obtained under the last twelve years of the old system it appears was as follows:—

"The following table shows the number of patents granted during the last twelve years of the old system:—

Year.	Number of Patents.
1841	440
1842	371
1843	420
1844	450
1845	572
1846	493
1847	493
1848	388
1849	514
1850	523
1851	455
9 months 1852	465

The numbers of applications for patents and complete patents, from the introduction of the new system to the end of 1862 have been as follow:—

	Applications for Patents not included in the next column.	Complete Patents.	Total.
3 months 1852	320	891	1211
1853	934	2111	3045
1854	954	1810	2764
1855	969	1989	2958
1856	1059	2047	3106
1857	1224	1976	3200
1858	1074	1933	3007
1859	1063	1937	3000
1860	1182	2014	3196
1861	1264	2012	3276
1862	1333	2157	3490
	11,376	20,877	32,253

The disproportion between these figures and those given in the previous table is enormous. By the removal of certain impediments, the number of patents granted in ten years and three months amounted to no less than 28,877, exceeding by 6,518 the total number granted in two hundred and thirty-six years under the old system. In addition to this there have been 11,376 applications, which, from various reasons, were not matured into complete patents. The change in the law, therefore, gave an enormous stimulus at the patent office. The sudden rise from about five hundred yearly to two thousand is very striking, and appears to be a good sign, whether it is due to any incentive given to inventive skill by the change in the law, or chiefly to inducements given to persons to take patents who would have been deterred from it by the old complex and expensive machinery. The following table will show in what directions many of the patents and applications have been distributed. Printed indices for 1863 and 1864 have not yet been published, and the figures for those years cannot therefore be safely given.

	*Railways and Railway Carriages.	Telegraphs.	Steam and other Boilers.	Steam Engines.
	Number of Applications.			
3 months 1852	48	12	45	49
1853	144	34	121	95
1854	134	33	81	98
1855	110	29	93	127
1856	155	30	115	109
1857	161	50	126	121
1858	127	108	150	121
1859	144	75	137	113
1860	134	68	142	145
1861	134	62	146	123
1862	127	57	137	127
	1418	558	1293	1228
Number of Patents to Oct. 1852	630	109	377	704
	2048	667	1670	1932

* Subdivisions.

Railways and Railway Carriages.—1. Permanent way, rails, rail-joints, chairs and sleepers; portable railways, atmospheric railways, tramways. 2. Railway switches, points, crossings, and turntables. 3. Railway carriages; coupling and uncoupling and altering position of carriages and engines. 4. Railway buffers and breaks; retarding and stopping trains; preventing collisions.

Telegraphs (Electric).—Telegraphic printing apparatus.

Steam and other Boilers.—Cleansing and preventing incrustation of boilers; water-feeding apparatus for boilers. 1. Constructing steam and other boilers; generating and superheating steam; preventing boiler explosions. 2. Cleansing and preventing incrustation in boilers; purifying the water. 3. Water-feeding apparatus for boilers; heating feed-water.

Steam Engines.—Stationary, locomotive, and marine.

		*Spinning.	Electricity and Galvanism. Electro-plating.	Sewing and Embroidery.	Heating and Evaporating.
		Number of Applications.			
3 months	1852	57	43	7	60
	1853	203	74	21	118
	1854	187	90	33	119
	1855	171	56	26	70
	1856	165	47	26	84
	1857	164	69	25	116
	1858	139	50	33	80
	1859	160	36	34	120
	1860	145	52	55	106
	1861	231	73	53	104
	1862	215	72	39	131
		1837	662	352	1108
Number of Patents to Oct. 1852		1120	38	40	373
		2957	700	392	1481

* SUBDIVISIONS.

Spinning and Preparing for Spinning.—1. Opening, ginning, breaking and cleaning fibrous materials. 2. Carding, combing, and heckling fibrous materials; making cards. 3. Roving, slubbing, spinning, twisting, doubling, and throwing fibrous materials.

Electricity, Galvanism and Magnetism, and their Applications.—Electro-plating and galvanising; depositing metal by electricity.

Sewing and Embroidery.—Threading needles.

Heating and Evaporating.—Regulating heat.

		*Fire Places; Grates.	Flues and Chimneys.	Fuel.	Ventilating Buildings, Carriages, Ships, &c.
		Number of Applications.			
3 months	1852	19	7	19	23
	1853	28	27	17	36
	1854	32	30	17	34
	1855	25	17	12	26
	1856	47	27	28	42
	1857	32	25	18	48
	1858	27	19	28	36
	1859	20	29	23	30
	1860	25	39	21	26
	1861	27	38	23	48
	1862	35	20	21	43
		317	278	227	392
Number of Patents to Oct. 1852		169	75	129	81
		486	353	356	473

* SUBDIVISIONS.

Fire places, grates and stoves; fenders and fire guards. Flues and chimneys; chimney tops; curing smoky chimneys; chimney windguards. Fuel; treating coal; preparing fire-wood; fire lighters. Ventilating buildings, carriages, ships, &c.; supplying diving bells with air.

The preceding tables will be perused both with interest and astonishment, and, perhaps, with the greatest interest and astonishment by those who are familiar with some of the branches of manufacture alluded to, but who have not been initiated in the records of the Patent Office. Of their correctness there can be no question. The records of patents for inventions are so lucidly arranged that statistical information is obtained with great facility. It is very evident that there has been a great deal of enterprise on the part of projectors. Subjects that have only come prominently forward within a few years, such as the applications of electricity, ventilation, and sewing machines, have nevertheless furnished considerable proportions, and it would be well if we could know to what extent the inventors have met with success. The following table will throw some light on this point. It appears that, though the number of patents increased after the Patent Law Amendment Act from about five hundred yearly to about two thousand, the number of persons who have paid the sum of fifty pounds after the expiration of three years for an extension of their patent rights for a further period of four years, has not much exceeded the number of persons who paid a far larger sum under the old law to obtain patent rights in the first instance. If the seven and fourteen years' patents of the first four complete years are added together, the yearly average of the eight complete years will be found to be about five hundred and sixty-three, showing a yearly increase of about sixty-six on the last eight complete years under the old law. It appears also that the number of persons who, under the new law, have paid the sum of one hundred pounds after the expiration of seven years for an extension of privilege for the full period of fourteen years, is less than half the number that paid in advance for the same period under the old law.

		Total Number of Applications.	Applications which did not become Patents.	Patents of three years' standing only.	Patents of seven years' standing only.	Patents of fourteen years.
3 months	1852...	1211	320	581	208	102
	1853...	3045	934	1490	416	205
	1854...	2764	954	1297	373	140
	1855...	2958	969	1438	356	195
	1856...	3106	1059	1474	359	214
		13084	4236	6280	1712	856
	1857...	3200	1224	1392	584	These cannot be divided between the seven and fourteen years' columns till the expiration of the first period of seven years.
	1858...	3007	1074	1394	539	
	1859...	3000	1063	1395	542	
	1860...	3196	1182	1435	579	
		25487	8779	11896	3956	856

The tabular view we have extracted speaks volumes, and shows that the present patent laws have only been productive of a quantity of rubbish without regard to quality; of the truth of this assertion considerable light is thrown by the superintendent of specifications, who, the author states has, in an appendix to his evidence in a recent parliamentary report, shown what is the real value of the first hundred applications for patents in the years 1855, 1858, and 1862.

A. D. 1855.

"Of the first hundred inventions, for which applications for patents were made in the year 1855, none are apparently of considerable value, but I believe it to be impossible to predict beforehand the value of any invention. Four of the hundred inventions appear to be of some, but not of great value, and patents were granted for all of them. One of these patents expired at the end of the third year of the grant, and two at the end of the seventh year; and consequently only one continues in force.

A. D. 1858.

Of the first hundred inventions, for which applications for patents were made in the year 1858, none are apparently of considerable value. Three of the hundred inventions appear to be of some but not of much value; and patents were granted for all of them; but these patents expired at the end of the third year of the grant.

A. D. 1862.

Of the first hundred inventions, for which applications for patents were made in the year 1862, one is apparently of considerable value; and a patent was granted for it, which is still in force. Of the same hundred inventions, one appeared to be of some but not of great value; and a patent was granted for it, which is still in force.

Therefore, according to Mr. Woodcroft's judgment, given with the caution that might be expected on matters of such complexity and variety, of three hundred applications, only one appeared to him to be of considerable value, and eight others appeared to him to be of some but not of great value. These conclusions are remarkable, and are even more unsatisfactory than the published statistics. If only nine patents out of three hundred applications appeared to possess some substantial value, there might be no more than ninety out of three thousand. But the table given above appears to show that of 3106 applications in 1856, 214 persons found their patents valuable to them after seven years."

It will be seen by what we have given from this work, that there is much curious matter that every person engaged in artistic work, manufactures, and scientific pursuits should read, and we strongly recommend it to them as containing much that is really valuable, although we must join issue against the notion the author appears to entertain, that the granting of patents are of but little value. It is our opinion that a true inventor should have protection by simple efficient laws for what he produces for the public benefit—without Government dipping their hands into his pockets, to give him a so-called protection, that in ninety-nine cases out of every hundred proves no protection at all; besides, why should the Government, as now, grant a monopoly to an inventor for any period of time—with the proviso that the public should use it at the expiration of the period, when it has in almost every case become superseded. The public instead should be enabled to use the invention from the completion of the letters patent, paying the patentee a proportion of the profits made by the user (without the interference of the patentee) provided he honestly keeps books—producible every quarter, to satisfy the patentee what his profit has been—the per-centage upon the profits being settled by the law governing inventors' patent rights.

CLARK'S PERMANENT WAY OF RAILWAYS.

(*With an Engraving.*)

This invention was recently patented by Mr. William Clark, of Chancery-lane, London, as a communication from M. Duméry, C.E., Paris. The patentee states that:—

The principal object in the employment of rails of railways, besides that of obtaining direction in a horizontal plane, is to procure a perfectly uniform running surface, which shall be always rigid and of sufficient section to be uninfluenced by the dead weight, and producing neither shock nor concussion, that is to say, preventing any vertical movement of the travelling body, which is kept in a plane perfectly parallel with that of the line. To ensure this result many methods have been employed, such as stone blocks, longitudinal walls, sleepers, and plates of metal or wood, provided with intermediate metallic supports or chairs. In many cases intermediate chairs are dispensed with by placing the rails directly on the sleepers, and fixing them thereto in any suitable manner; it has also been attempted to place the rails directly on the ballast without any other accessory than the necessary means for prese ving their parallelism, notwithstanding which completely satisfactory results have failed to be attained. Stone blocks, from their rigidity and bulk, would suffice if continuous, and were it not from their very nature they oppose an intermittent inertness, the destructive effects of which tell both on the line and rolling stock, causing a wear at each point of support of the rail which renders the latter unsuitable for turning, by means of which it is rendered longer available for use. Hence it is only with moderate speeds, comparatively heavy rails, and light rolling stock, that stone has produced a favourable result, but with carriages or engines of sufficient weight to produce deflection of the rails, the bulk and rigidity of the stone possesses disadvantages which it is sought to remedy. Now as it is impossible to increase the weight of the rails sufficiently to prevent deflection, it has been supposed that by forming the supports of a comparatively elastic substance, one portion of the shock would be absorbed. Hence the employment of wood has become almost general; but whether it be employed in the form of longitudinal or cross sleepers, the shock is only deadened at the expense of the wood, which becomes quickly worn by the iron, and is thereby rendered of limited durability. In order to remedy this in some measure, single-headed rails have been used, which are not reversible, and present a flat surface at bottom applied direct on the wood, to which they are fixed by the aid of wood screws or otherwise. These rails, which are termed Vignole rails, are in many places preferred to those with double heads, but the absence of the solidity imparted by cross sleepers, their isolation and want of resistance to lateral strain, together with the imperfect connection of the iron and wood, and the wear of the latter, tends to limit their use. Rails have also been made in the form of an inverted V, and known by the name of Barlow or sleeper rails, but these possess the following disadvantages:—1. They can only be made in short lengths in consequence of their weight, and thus they multiply the joints, which it is sought to avoid. 2. They are liable to spread, and be crushed under the influence of the loads passing over them. 3. Their bearing surface on the ground is limited to that of the rail itself, not extending beyond the width of the line. 4. They are only fixed by the ballast in which they are laid, which is always uncertain in its nature. 5. It is necessary, in order to renew the wearing surface, to re-form not only that part, but also the support itself which is uninjured. 6. The subsistence of the line from the above causes produces longitudinal undulations to a large extent, creating a lateral rocking motion, which impairs the stability of the rolling stock, and at considerable speeds proves a source of much danger. It is thus clear that it has been sought, although very imperfectly, to remedy the various disadvantages of existing railroads, by joining the flexibility and instability of wood to the flexibility of the rails. It is further necessary, in order to allow of considerable speeds being attained, to use larger and heavier chairs and stronger and heavier rails, and even with this augmentation of the weight of the rails, as the deflection is in direct proportion to the square of the distance between the supports, it becomes further necessary, in order to obtain an adequate result, to place the cross sleepers nearer together, and so multiply their number; and it is only by uniting all these conditions that a partial remedy is attained, and which can only be either removed by the employment of a continuous bearing possessing neither flexibility nor elasticity. Thus it is only by complete rigidity, which has hitherto been abandoned only through the impossibility of attaining it absolutely, that the true qualities of a railroad can be realised. Thus it is by obtaining continuity in the construction of the rail, and also in the means of fixing the same, that I hope to obtain as a result a line which shall possess a smooth running surface, durability, be economical in construction and maintenance, and at same time tend to preserve the rolling stock.

The objects of this invention are thus various, and consist in the employment of a rail of a different metal to that of its support in order to obtain the necessary qualities from each; to dispense with accessory parts, such as the chairs, wedges, keys, and others, the cost of which is not compensated for by increased wear of the rails or supports; to unite the rail directly to its support, and so intimately as to dispense with the ordinary fish-plates, or rather to obtain a continuous fishing of the rails; to combine a rail with changeable head with a metal sleeper forming part of same; to render the surface in contact with the ground not only continuous, but superior to the plans now adopted on the best lines; to obtain all these advantages by the aid of ordinary forgings, at same time ensuring the perfect junction of the parts; lastly, to render their adaptation as easy as with the systems ordinarily adopted, placing the whole, where circumstances will admit, on a macadamised surface previously prepared.

The means for carrying this invention into effect are very simple. I first take a piece of iron and roll it of a T form, the width and depth of which are such that on inverting the T the width of its base shall present a sufficient surface to sustain the weight and prevent the crushing of the line or sinking of the ground, while the vertical part offers the requisite additional support to the rail for sustaining the heaviest loads. A single-headed rail, also obtained by rolling, is connected by bolts to the vertical part of the T iron in such manner as to form but one whole, and presenting the appearance of a Vignole rail of the amplest dimensions, and constructed of two parts having butt joints. Cross sleepers are applied for connecting the two rails of a line, and serve to complete the arrangement. The ends of the cross sleepers being turned up in hook form, a single bolt is sufficient at each end to prevent any deviation from the plane of the sleepers, and to give the whole perfect rigidity.

I do not confine myself to the precise form or dimensions of this sleeper, nor to those of the rail and longitudinal rib, as they may be varied according to the nature of their application, although changing nothing in the basis of the combination forming the subject of the present invention.

The principal features of this combination are—1, the adoption of a rail sleeper or sleeper rail, forming one and the same piece; 2, this sleeper rail possesses an advantage hitherto sought for unsuccessfully in single rails, it being composed of two metals of different densities, the one renewable and the other permanent; 3, it possesses the same simplicity of arrangement and construction as the Barlow rail; 4, the adoption of butt joints forming continuous fishing; 5, dispensing with the many points of contact causing continued wear in ordinary chairs; 6, obtaining continuous contact with surfaces comparatively incapable of injury; 7, heavy forgings are not required; 8, the whole of the metal is utilised, as also the resistance of both parts of the rail; lastly, the line may be laid on a macadamised surface previously prepared. The lower part thus acts as a sleeper having sufficient surface as a rail in perfecting the resistance to deflection, as a chair in its opposing any tendency to become overturned, and as a fish-plate from its being arranged with butt joints. The upper part of the rail, properly so called, answers either the double purpose of resisting any tendency to deflection, and presenting a hardened surface to prevent crushing, or it may be with the latter object only.

If it is wished to diminish the weight of the rail proper, or if instead of making the iron denser it be constructed of steel, and consequently economised in weight, the vertical part of the sleeper should be of sufficient strength of itself to bear the weight, the head of the rail being applied thereto either by means of ears secured by bolts, or by means of a groove, and fixed by keys, pins, bolts, or otherwise.

The rails are fixed in position on the line by simply embedding in the ballast as in ordinary, or by previously hardening the ground and laying the rails in mortar or cement, leaving openings for receiving the cross sleepers, which are then consolidated by filling in dry rubbish, or it may be suitably cemented. It is unnecessary to add that the water is carried off as in ordinary by the inclination of the surface, with or without natural or artificial subsoil channels.

The patentee further states that he has confined himself to one example of the method of application, considering it unnecessary to multiply forms having but one single object, and which will be understood from the foregoing description. The invention thus comprises two essential points:—1, the rail, and 2, the previous hardening of the ground, the rail being applied in any suitable manner, and the improved foundation being applicable whatever may be the form or system of rail to be used: each of which improvements may be employed either separately or in combination.

References to Engraving.

Fig. 1 (Plate 29) represents a transverse section of a sleeper rail furnished with its cross sleeper; Fig. 2, a longitudinal elevation, and Fig. 3, plan of same; Fig. 4 represents a rail laid on a macadamised surface with a bed of cement interposed, which latter, in order to compensate for its friability, may further have a thickness of wood or other substance applied; Fig. 5 represents a rail, the head of which is formed of a harder metal. *a*, single-headed rail; *b*, sleeper carrying the rail; *c*, bolts for uniting the parts together; *d*, cross sleeper; *e*, hooked ends of sleeper; e^1, bolts of sleeper.

Institution of Civil Engineers.—The Council of the Institution of Civil Engineers have awarded the following premiums:—

1. A Telford medal, and a Telford premium in books, to J. W. Bazalgette, M. Inst. C.E., for his paper "On the Metropolitan System of Drainage, and the Interception of the Sewage from the River Thames."
2. A Telford medal, and a Telford premium in books, to C. Reilly, A.I.C.E., for his paper "On Uniform Stress in Girder Work, illustrated by reference to two bridges recently built."
3. A Telford medal, and a Telford premium in books, to E. H. Clark, for his "Description of the Great Grimsby (Royal) Docks, with a detailed Account of the Enclosed Land, Entrance Locks, Dock Walls, &c."
4. A Telford medal, and a Telford premium in books, to Capt. H. W. Tyler, R.E., A.I.C.E., for his paper "On the Festiniog Railway for Passengers; as a 2-feet gauge, with sharp curves, and worked by Locomotive Engines."
5. A Telford premium in books, to J. England, M. Inst. C.E., for his paper on "Giffard's Injector."
6. A Telford premium in books, to T. Hawthorn, for his "Account of the Docks and Warehouses at Marseilles."
7. A Telford premium in books, to E. Fletcher, for his paper "On the Maintenance of Railway Rolling Stock."
8. A Telford premium in books, to E. Johnston, M. Inst. C.E., for his paper on "The Chey-Air Bridge, Madras Railway."
9. A Telford premium in books, to G. O. Mann, M. Inst. C.E., for his paper "On the Decay of Materials in Tropical Climates, and the methods employed for arresting and preventing it."
10. A Telford premium in books, to W. J. W. Heath, A.I.C.E., for his paper "On the Decay of Materials in Tropical Climates, and the methods employed for arresting and preventing it."
11. A Telford premium in books, to J. Taylor, A.I.C.E., for his paper on "The River Tees, and the Works upon it connected with the Navigation."
12. The Manby premium in books, to H. B. Hederstedt, A.I.C.E., for his "Account of the Drainage of Paris."

Ventilation.—General Morin read a paper, very recently, to the Academy of Science, on the ventilation of public buildings. The fundamental principle of good ventilation, he observed, was this:—To draw off the vitiated air from the stratum nearest the floor—that is, in the immediate vicinity of the persons in the room, and to admit pure air through the ceiling or apertures made in the walls close to it. In winter the air to be introduced may be previously warmed by an apparatus placed under the roof; but in summer considerable difficulty is encountered in lowering the temperature of the air to be admitted, since the sun having darted its rays upon the roof during the day, the space under the roof is so hot that, instead of admitting cool air, it penetrates into the building at a much higher temperature than that of the interior. General Morin has tried four different plans for cooling the air. The first consisted in making it pass through a space filled with pulverised water—that is, reduced to a sort of dust, as it were, by making two jets of water strike against each other with great violence. By this method the temperature is only lowered by two degrees, and moreover, it would require a considerable quantity of water and costly machinery to effect it, unless ample water power were at command. The second plan consists in making the air pass along the sides of metallic vessels containing water, which may, if necessary, be cooled with ice; but here again there is the difficulty of giving the cooling surfaces a sufficient development —a condition which cannot easily be complied with, and which therefore, in point of fact, renders this method impracticable. The third consists in making openings on that side of the building which is never exposed to the action of the sun, while the vitiated air is drawn off through metallic tubes, the draught of which is increased by the action of the solar rays to which they are exposed. On the side exposed to the sun the windows should be closed with blinds, or in the case of skylights the glass panes may be watered outside. The fourth process will be easily applicable as soon as Paris can command abundance of water by the new acqueduct of the Dhuys. It imitates the natural effect of rain, and is very efficacious, since one cubic metre and a third per hour will suffice to water 100 square metres of roofing, which will thus be prevented from being overheated by the sun. Applied from an early hour in the morning, and continued as long as the sun shines on the building, it not only prevents the roof from getting hot, but will reduce the interior temperature of the building very considerably, and cool the air admitted into the garret or space under the roof. As this operation of watering need not be performed for more than sixty days every year, the cost for a large railway station like the Orleans one, for instance, would not exceed 1000f. each season.

Cost of Great Drainage Works.—In consequence of the terrible disasters which occurred in 1856, when the whole of the great basins of France were inundated, a careful inquiry and surveys were made, and in 1858 a law was passed for the carrying out such works as should insure the towns which had suffered most against future inundations. Works have been executed with that view in forty-five towns, at an outlay of twenty-two millions of francs, or £880,000. As regards the great valleys, the Imperial Government appointed an inspector-general for those of the Seine, the Loire, the Rhone, and the Garonne, and the result of all the surveys and inquiries that have been made was made known to the Corps Legislatif by M. Franqueville, the government commissioner, in the following words:—"Are you aware, gentlemen, what it would cost to reduce the level of the waters in these valleys, say 2 or 3 feet, during great inundations?—For the valley of the Loire it would require eighty-five reservoirs, which would cost a hundred millions of francs (four millions sterling), and the same for that of the Rhone. We have not dared to undertake such an enterprise, to ask the country to make such sacrifices in order to prevent a misfortune that only occurs two or three times in a century." The valley of the Rhone was inundated in the years 1840, 1841, and 1856, and that of the Loire in 1846 and 1856. The opinion of those who have inquired into the subject is, that such inundations cannot be attributed to any changes that may be made in the quantity or distribution of timber in the localities, but that the facts observed during eight or ten centuries prove that they are the result of a concurrence of a certain number of atmospheric circumstances, which fortunately happens but seldom. Another conviction forced upon the government engineers is, that the plans proposed are of very questionable efficiency, and upon this head a report is promised of the results of all the examinations that have taken place under the general council of engineers having charge of the roads and bridges of the empire.

Great Prize in Voltaic Electricity.—The French Government has just announced the renewal of the grand prize of 50,000 frs. to be given, in five years' time, to the author of a discovery which shall render the voltaic pile economically applicable as a source of heat, as a means of lighting, or otherwise, in chemistry, mechanics, or medicine. This prize was awarded, in September last, to M. Ruhmkorff, for the well-known apparatus which bears his name. In case no invention deemed worthy of the honour should be brought forward within the time specified, the period may be prolonged for another five years by decree. The prize is believed to be open to all the world, but it is not so stated.

Paris Universal Exhibition of 1867.—The mimimum amount of guarantee having been subscribed for, the Imperial Commission has added nineteen members to its body, as representatives of the guarantors provided for in the original degree. The list includes several names well known in the financial and industrial world, as MM. E. Perèire, P. Talbot, the Duc d'Albufera, Baron James de Rothschild, Sallandrouze de Lamornaix fils, Desfosses, and Halphen.

J.R. Jobbins

NATIONAL SCHOOLS ST PHILIPS DISTRICT, CLERKENWELL, LONDON.
To accommodate 150 Boys. 150 Girls and 150 Infants.
R.J. WITHERS, ARCHT A.D. 1864

SCHOOLS, CLERKENWELL, LONDON.

(With an Engraving.)

The large district of St. Philip, Clerkenwell, with a population of nearly 10,000 persons, being without schools, means have lately been taken to secure a site; after some years' fruitless labour, two freehold houses have been purchased of the Metropolitan Railway Company, the land of which when cleared will have cost the committee at the rate of above £20,000 per acre. The property has frontages in King's-cross-road, and in the side street leading into Granville-square, and is consequently very suitable for its purpose. It is intended forthwith to erect schools for 150 infants, 150 girls, and 150 boys, on three separate floors, with cellarage under, to be turned to profit by letting. The infant school will be on the ground-floor, 40 feet by 30 feet; the girls' school over same, and of similar dimensions, both entrances will be in the side street; the boys' school will be on the second-floor, 46 feet by 30 feet, and entered from King's-cross-road.

The materials used will be common stock bricks, relieved with Suffolk red bricks in bands and arches: the floors will be fireproof, upon Fox and Barrett's system; no plastering will be used internally except to ceilings. The estimated cost is £3200. Mr. Withers, of Doughty-street, London, is the architect.

WANTED: A NEW SOCIETY OF ARCHITECTS!

(Concluded from page 253.)

Most creditable to the members of our various architectural and archæological societies is the fact of their association for the laudable objects in view, whether these be of mutual improvement by the interchange of ideas, or of mere intellectual amusement. It may be fairly assumed that, in London at least, the two most important of these societies absorb within their respective muster rolls some of the most distinguished (because the most studious) men in our liberal profession. Yet, some there are that stand, and have ever stood, aloof from them. Not to mention living architects of eminence, some of whom have never been members, and others who, if now members of, say the Institute of Architects, had attained a European eminence in their profession long before their joining that body, there is the late Mr. Welby Pugin. He was never a member of the Institute, and yet no one will deny him a niche among the worthies of the architectural profession; and what is more to our purpose, he never lacked patronage or public estimation for want of being a fellow or an associate of that society or corporation.

On that last word "corporation" we will suspend, as on a convenient peg, a few practical considerations of the present insufficiency of all our architectural societies. They do nothing for the public, as do the College of Physicians, the Apothecaries' Company, the Trinity Board, and such other societies or corporations. The medical practitioner or the mariner, who seeks public recognition and employment, *cannot* safely ignore the proceedings of such bodies as these. He *must* succumb to their influence. But, alas! how different is it with the architect. We architects possess an incorporated society, but what cares the architectural quack for the proceedings of the Royal Institute of British Architects? He can with impunity emulate the sturdy "navvy," thumped by his diminutive wife, and say of the periodical gathering of the fellows and associates of the Institute, "It amuses them, and it does not hurt me." The Institute is powerless to put down the quack, and what is even worse than all, cannot even afford to play *tu quoque* with that worthy, and ignore him. And thus it happens that, every now and then, when Mr. John Bull takes to a sudden craving for high art on an extensive scale, and forthwith desiderates a palace, or a what-you-will in the way of brick-and-mortar-and-plenty-of-it, up starts some unknown, "ill-conditioned and unkempt" *outsider*; and, to the intense disgust of the whole profession in general, and of the fellows of the Institute in particular, gobbles up the tempting morçeau (*Anglicé* "big job") before their very eyes. It is really too bad for anything; especially when one reflects that our Institute of Architects is incorporated, and really aspires, in its own way, to define "Who's who" in the profession.

Now this definition is the very thing that is wanted; and surely, when we look round, and see the unsatisfactory state of the profession, there must be something radically wrong in the Institute's way of defining who is, and who is not, an architect; who is "a good fellow," who is an indifferent one, or mere associate, and who is a quack or black sheep. A few young men go up to the Institute for the minor and major examinations (excellent things in their way), but already we hear them complain, "Of what use to me is the passing these little and great 'goes,' if the public are to know nothing of it; and the Institute is to go on manufacturing fellows and associates over my head, without even subjecting them to some process of preliminary quarantine or fumigation, say 'the little-go?'" Is there no means of altering the constitution of the Institute; or in other words, of forming "a New Society of Architects?" Something should surely be done to protect the young and often friendless students of a precarious profession, particularly in the Metropolis, where, of all places in England, it is perhaps the most difficult matter for a young man of talent to rise into independent practice.

Nor let those last words be misunderstood. We do not desire to see young men of *mere* talent jump all at once into independent practice. There is enough of that already: if not in London, in the provinces, where the popular notion of an architect seems to be, that a youth with a facility for drawing is all that the public require. There we very often see the London use reversed; and the design, construction, and pecuniary adjustment of vast works entrusted to young fledgelings, who ought to be completing their elementary training; if, poor souls, we could only tell them where and how to do it.

Then what sort of society of architects shall we set up in exchange for the present unsatisfactory ones? Surely some society that will winnow the profession of its sheep, and separate them from the goats, with whom they are mixed up in heterogeneous confusion. Why cannot the Institute of Architects make a beginning, and by conferring, at a small matriculation fee, an Associateship on such gentlemen as pass its "little go," and a Fellowship on such as pass its second examination, form within its own body the *nucleus* of such a society?

Or, some society might be formed, whose leading men might be such as have distinguished themselves in one or more of those three branches of professional "craft," which are now pretty well acknowledged as the *material* for a complete, or rather mature architect:—1. Artistic power; 2. Scientific knowledge; 3. Professional knowledge; or, what has been well called, "The Lamp of making a Living." These three branches of professional excellence, have been often dwelt on by architectural writers; and most writers know in and of what they respectively consist. In such a society one man, whose capabilities for fine art were insignificant, might find a congenial home as a professor of, say architectural science; and in all cases of difficult construction, purely scientific, or of difficulties in ventilation, sound, salubrity, &c., the public would know where to find "the right man in the right place." Again, another man, who, though little of an art-architect, and no great man of science, was skilled in professional lore or office practice, would be well found in such a society by those who happened to need an arbitrator in a disputed building contract, or as the case might be; while to the juniors or undergraduates of the society the very fact of the three kinds of graduate—say the art-architect, the science-architect, and the practice-architect, with such as happened to hold two or all the three degrees—being all welcome children of the same *alma mater*, would act as a sharp incentive to the energies of the younger men. They would at least know what were really the branches of information necessary for themselves in after life; and they would, with the general public, know to whom to have recourse as authorities in all the three departments of their profession.

To confine ourselves, as now, to fortnightly papers over tea and coffee, with the mere enrolment of members, who die, fall away, and from time to time have their dreary ranks re-filled, is sheer misuse of time and means, save, as we before observed, for purposes of mutual improvement and amusement, while we see and approve of something better. Let the members of the Institute look round, and, counting their increased numbers since its formation more than a quarter of a century ago, determine wisely whether English architects, and Metropolitan ones especially, are held in as high estimation by the general public, as are the members of the legal and the medical professions, who judiciously resort to a severer system of showing the public who are, and who are not, their great men.

Solomon Setsquare.

IMPROVEMENT OF TOWNS.*

By James Lemon, A.I.C.E.

No. III. *Drainage.*

The drainage of towns is perhaps one of those subjects to which the attention of the general public has been called more than any other. It is likewise one upon the general principles of which there has existed considerable difference of opinion amongst the leading members of the engineering profession. Most persons recollect the brick-sewer and stoneware-pipe controversy: happily that has died a natural death, and the most energetic opponents of pipes and supporters of brick sewers on the one side, and the most sanguine advocates of pipe drainage on the other, have settled down to one general opinion; that a combination of the two systems properly applied gives economical and satisfactory results.

It is much to be regretted that in the practice of the art of town drainage, so little regard has been paid to the means so bountifully provided by Nature for the removal of the surface water.

Man, in selecting a locality for his habitation, naturally prefers a position near a river, as he thus provides for his wants with the least labour to himself: and so villages and towns adjacent thereto have sprung up. The water supply is drawn from the river, or nearest stream or spring: and the animal ordure and other refuse is deemed to be satisfactorily got rid of if it is allowed to pass into the same source. As a natural consequence the streams become fouled; and when an epidemic therefrom appears, then the local authorities turn their attention to remedying the evil; the waterworks are perhaps removed higher up the river; but the same pollution of the streams still goes on. We may however hope soon to see some improvement in this respect: the Local Boards of Health are arriving at a true sense of their former follies, and the system of making the rivers which run through our towns, the Grand Sewers, will soon be abolished. With increased powers enabling the local authorities of two or more districts to join together in one common plan, and distribute the sewage over the country, a new era in drainage will be commenced, and a fair field will be opened to engineers to convert and adapt the great sources of power in nature to the use and convenience of man.

Sir John Rennie, in his excellent letter to the *Times* on drainage,† says: "The great object has been to get rid of the superfluous water from the land at any cost. This, no doubt, is very important and indispensable for good agriculture, and vast benefits have resulted therefrom; the consequence, however, has been that the rainfall is carried off almost as soon as it reaches the surface of the soil, and has no time to percolate into the water-bearing strata below, so that the subterranean springs are, for the most part, deprived of their wonted supply, more or less, according to the geological structure of the districts in which they are situated; hence, also, the floods rise more rapidly, and are carried off more quickly than before.

Now as there is only a certain quantity of rainfall in each district, and as that usually takes place during the winter and autumn months, it naturally follows that during the summer months, with a diminished rainfall, dry soil, almost exhausted springs, and a higher evaporating temperature, the rivers and streams drain lower than formerly. This evil is further increased by the whole of the sewage matter being discharged into the nearest watercourses, so that these are practically choked up, navigation is impeded, the water is contaminated, the atmosphere is rendered unhealthy, and the inhabitants are deprived of that supply of pure and wholesome water which is absolutely essential to their healthy existence."

Let us now consider some of the leading points to be observed in preparing a scheme for town drainage. The first question which arises for solution is, the disposal of the rainfall. Upon this branch of the subject, there is a difference of opinion amongst drainage engineers. It is thought by some that the rainfall should not be taken into account at all in determining the area of the sewers, whilst on the other hand it is contended that provision should be made for a greater portion thereof.

In the report of Messrs. Bidder, Hawksley, and Bazalgette, in 1858, it was shown that a large proportion of the rainfall was evaporated or absorbed, and did not pass through the sewers. It was also estimated by those gentlemen that upon an average ¼ of an inch of rainfall would not contribute more than ⅛ of an inch to the sewers, nor a fall of $\frac{4}{10}$ths of an inch more than ¼ of an inch. From observations made of the quantity of rain falling on the metropolis within short periods, it was found that on an average of several years, while there were about one hundred and fifty-five days per annum upon which rain fell, there were only about twenty-five days upon which the quantity amounted to ¼ of an inch in depth in twenty-four hours, or the $\frac{1}{100}$th part of an inch per hour if spread over an entire day. It was, therefore, considered if ¼ of an inch of rainfall was provided for, there would not be more than twelve days in a year on which the sewers would be overcharged, and then only for short periods during such days.

Now let us investigate the difference of area of sewer which is caused by the provision for ¼-inch of rainfall spread over 24 hours. If we take 30,000 persons to the square mile, and 5 cubic feet as the average water supply per head per diem, we shall have a quantity equal to 150,000 cubic feet, half of which will have to be disposed of in six hours, which is equivalent to the whole in twelve hours. Then if we take ¼ of an inch of rainfall falling on a square mile of surface, we shall have 580,800 cubic feet of water spread over twenty-four hours, or 290,400 cubic feet to be carried off by the sewers in twelve hours, which is nearly double the quantity of water supply estimated, and necessarily involves an increase of area of sewer from 1 to 3.

It will thus be seen that the rainfall plays a very important part in town drainage, and that if it is provided for in the area of sewers, it increases the size very considerably and consequently the cost. But cannot this enormous area for rainfall be reduced? Is it absolutely necessary? According to the report of Messrs. Bidder, Hawksley, and Bazalgette before mentioned, when there is a fall of ¼ of an inch, ⅛ of an inch only finds its way into the sewers; then why provide for ¼ of an inch? Why provide so large an area for rainfall, when for more than half the year it is entirely useless? It not only increases the first cost of the sewers, but likewise the annual cost of pumping, as it must be taken into the main outlet sewer, instead of being discharged from the high-level districts by means of overflow sewers into the natural watercourses or streams.

The system of taking a large proportion of the rainfall to the outlet is likewise objectionable with regard to the utilisation of the sewage, although it contains great fertilising properties, as it must either be thrown upon the land when it is already saturated with rain and is least required, or it must be stored. Mr. R. Rawlinson, C.E., in his valuable list of rules and suggestions relative to sewers and drainage, recommends the improvement of valley lines and natural streams, so as to remove more readily surface water and extreme falls of rain. He is also of opinion that flood water may in most cases be passed over the surface without injury.

There is no doubt that a considerable portion of the rainfall which is now carried off by the sewers in many towns, might be saved by the general adoption of rain-water cisterns to the houses. Rain-water for washing purposes is really a valuable commodity, as each degree of hardness destroys 2½ oz. of soap in each 100 gallons of water used for washing. Soft water is also more wholesome, and effects a saving in generating steam power, and in other operations.* Rain-water might also be prevented from entering the sewers in such large quantities, by the adoption of considerably larger gullies in the streets. They might be constructed with an internal cast-iron cylinder of the same form as the present gullies, with perforations at the top, so that the water might overflow into a large brick chamber or well, and the iron cylinder would retain the mud and sediment. There could also be an overflow pipe from the brick chamber to the sewer, so that it could never become overcharged. Or the same might be effected in a simpler and cheaper way, by retaining the present form of brick gully, and constructing a well about 3 feet in diameter, connected therewith by an overflow pipe. This well could in many instances be sunk down to the water-bearing strata at a small cost, or communicated therewith by means of boring. It could be constructed in the ordinary way, by a curb, steined below the water level, and above built up in brickwork in cement. It could also be connected with the main sewer, at, a point below the level of the basements of adjoining buildings or immediately above the level of the soffit of the sewer. Provision could also be made for a pump, by a socket cast on the

* Continued from p. 221.

† *C. E. & A. Journal*, May 1864.

* Mr. Rawlinson on water supply.

cover of well, brought up to the surface of the footway, for the purpose of watering the roads and washing the paving. This would require more labour than using the water supplied by the water companies, but experience has shown that it is, notwithstanding, a considerable saving of outlay. It would also economise the pure water, of which we are at the present time rather prodigal, which in many countries where it is scarce, the inhabitants go to great expense to retain, whereas we on the contrary, give ourselves an immense deal of trouble at great cost to get rid of.

By thus adopting every available means of storing the rainfall, a considerable saving is effected in the cost of the sewage, by the consequent decrease of the area of the sewers. The storm or flood waters can be provided for, by utilising the natural streams and valley lines (which in no case should be arched over and converted into main sewers) and by the construction of overflow or supplementary sewers from the main intercepting sewers to the nearest available stream or outlet.

The second point to which we should direct our attention, is the area required for carrying off the sewage proper. This will depend on the water supply in the particular town or district. The supply of water to ancient Rome was computed by Prof. Leslie at 50 cubic feet, or 312 gallons per head of the population. The water supply to the Metropolis is calculated to average about 5 cubic feet per head: this includes the supply for ordinary domestic purposes, manufactories, supply to public buildings, baths and washouses, &c., extinction of fires, cleansing and watering of streets, &c. There is no doubt that much of this is wasted by the use of defective cisterns, water-butts, ballcocks, &c.

It is to be hoped that we shall eventually succeed in getting rid of the present monopoly, and in obtaining the great desideratum in water supply, viz. constant service. By constant service, chargeable by meter, the consumer pays according to what he uses and no more. Its superiority over the intermittent principle is so well known that it is scarcely necessary to enlarge upon it in the present treatise, but with a view to keep the subject before the readers of the Journal, the following list of advantages it offers is given.

1. Saving of water.
2. Saving of the first cost of cisterns, with all the expensive connections.
3. Purer water, as it is well known the receptacles for water are imperfectly cleansed, badly constructed and covered, being frequently exposed to the action of the sun, and open to the entrance of soot and dirt of all kinds.
4. Non-liability to the inconvenience of finding the cisterns empty, or their contents reduced to a few inches of muddy water.
5. Economy in the sizes of the mains and service pipes, as the delivery is distributed over a longer period.
6. Non-liability of the pipes to bursting, by the sudden rush of water, which compresses the air within.
7. The pipes are less liable to corrode, as they are not subject to the alternate absence and presence of water.
8. Its application as a motive power to machinery.
9. Superiority in the preservation of life from fire; and,
10. Comfort and health of the inhabitants.

The question of water supply is so closely allied to that of town drainage, that one cannot well be considered without reference to the other; hence the advisability of the construction of waterworks being undertaken by the local boards, and not by private companies.

Having determined the amount of rainfall and the water supply, it only remains to calculate the size of the proposed sewers according to the drainage areas, the population present and prospective, and the fall to the most convenient outlet.

Now let us suppose, for illustration, that we have to drain a town situate next a river, and that the land next the banks thereof is the lowest point. Probably, the best mode of disposing of the drainage areas would be to arrange them so that the sewers into which they drain may be, as much as possible, parallel to the river. By this means the sewage can be collected at two or more levels, according to circumstances. Then, having first disposed of the highest level (which we will call A), taking care that we have included all the area possible to drain thereby, carry it to the most convenient spot outside the town for manuring purposes. Then take into consideration the next level (B), and dispose of it in the same way as described for A, but do not connect the two together at any point. Then take the next level (C) immediately below B, in like manner, and so on until the whole area is complete. It will then be necessary to construct overflow-sewers, at the most convenient points, at right-angles to A, B, C, &c., which can be connected therewith on the lower side, after having passed under the same, the area being increased at the junctions at B, C, &c., and then continued to the river.

This principle of drainage simply means, when you have sewage at a high level, keep it there until you can utilise it, and do not carry it down to the lowest level at great cost, where it is useless for agricultural purposes, and must be pumped up again before it can be distributed over the land.

It may be argued by those in favour of providing for a large rainfall, that if you do not take the heavy rains and storm waters in your main sewers, you must do so in your overflow sewers. This is true, but the area thereof is not increased in the same ratio, because you are able to avail yourself of every means of outlet, as the sewage is so excessively diluted that it is quite innocuous, and in no way injurious to the streams into which it is discharged.

Forms of Sewers.—Sewers were formerly designed, and in some cases at the present day, by the ignorant in such matters, on what is called the safe principle—that is, to make them large enough. But, from the numerous experiments which have been made, it is found that excess of surface is to be avoided as much as deficiency of fall. A sewer which is disproportionally large in comparison to the work which it has to do, becomes, in course of time, inoperative from the accumulation of deposit consequent upon the sluggishness of the flow; but if the sewage is concentrated by decreasing the width of the channel, greater rapidity is produced. It is well known that a circle includes a greater area within a given perimeter than any other figure; consequently, it exposes less surface to friction, and therefore is a good form for a sewer or drain. It likewise requires less material, and is therefore the cheapest form. It has been generally adopted for the main intercepting sewers of the Metropolis; but for the minor branches, and for the district sewers, the form known as the inverted egg shape was preferred, as it gives the greatest hydraulic mean depth; consequently, the greatest velocity of flow at the bottom when the sewage therein is at the minimum depth. The upper part of the section being broader, it gives room for the shoulders of the workmen engaged in making drain connections or in cleansing the sewers.

The velocity necessary to prevent deposits in pipes and sewers is stated by Beardmore* at 150 feet per minute=$1\frac{3}{4}$ mile per hour, this generally speaking agrees with the statements of other eminent authorities on the subject. Prof. Robison states that a velocity=180 feet per minute=about two miles per hour, will sweep along stones the size of an egg. But looking at the question in a common-sense point of view, the best way to prevent deposits in pipes and sewers is to use every possible precaution in the construction of the gullies, ventilators, and other connections, so that the minimum quantity of the detritus from streets and roads is allowed to enter. The chief cause of deposit in sewers, setting aside the defects in form, is the want of proper cesspits to the ventilators, the insufficient size of the gullies, the absence of proper and regular supervision, and the want of gratings to check the flocculent matter, and sunk pits or tanks to receive the sand, &c., washed from the high lands at the connection of the sewers with the open ditches, which have been erroneously allowed to be converted into open sewers. Also no connection should be allowed to be made into any public or private drain for surface drainage (under penalty) without the provision of a properly constructed sunk trap or cesspit, which would have this advantage, that when it became choked the drain would be stopped, and therefore it would be kept cleared out.

Another cause of deposit in sewers, is the practice of throwing every kind of refuse from slaughterhouses down the drains. This under proper inspection could be prevented; as it is, some tons of guts are deposited in the Thames annually from the Fleet sewer alone. From experiments made thereon near the outlet, under Mr. Roe, it was found that the animal and vegetable matter and detritus from the streets, held in suspension, was 1 in 96. Also that the matter conveyed was 7·21 cubic feet per minute, or 103,660 cubic yards per annum;—a very good

* Beardmore's Hydraulics.

proof of the necessity and economy of catching as much as possible at the inlets and checking the abuse of the private drains.

If any further proof is required of the extravagance in neglecting proper precautions at the inlets to sewers, Paris affords rather a striking one. From the want of cesspits and gullies, the whole of the sweepings of the streets is washed into the sewers. It is then flushed into the Seine at a cost, during a recent year, of about £30,000, exclusive of the annual outlay of £3200 for dredging away the mud accumulated on the river bed opposite the outlets of the sewers.

The sewers as at present constructed in the metropolis stand out in favourable contrast to those of former times. They are mostly built of gault clay bricks, the invert being in Portland cement, and the arch in blue lias mortar, excepting in the low-lying districts, where they are entirely in cement. Every possible care has been taken in preserving a true form and level; so that they present a perfectly smooth surface, and therefore there is very little doubt will be, to a great extent, self-cleansing.

THE NEW INFIRMARY, SWANSEA.

(With Engravings.)

In our August number we gave a view and block-plan of the Infirmary to be erected at Swansea. In continuation of the subject we now present plans of the two principal floors.

The building is divided into three blocks or pavilions, connected on the ground-floor by a corridor, 9 feet wide. The central block is appropriated entirely to administration; the two others being the hospitals proper—one for males, the other for females. On the ground-floor of the female hospital is the dispensary, with separate waiting-rooms for males and females, with distinct approaches, and having covered communication with the salt-water bath-house. There will be also rooms for the resident dispenser. The ward arrangements are the same for both males and females, consisting of one large and one small ward, under the same supervision, and with similar scullery and other ward-offices. A small ward for eye-cases is provided in the rear of the central pavilion, and will be under the supervision of the head-nurse on that floor. The nursing-staff will consist of, in addition to the three head-nurses, nine day-nurses and three night-nurses, allowing two nurses for each large ward, and one nurse for each small ward. The whole of the nursing-staff (excepting the head-nurses) will have separate dormitories on the upper floor of the central block; those for the night-nurses being kept separate from the others. The kitchen offices are in the half-basement story of the same building, with one general lift for diets, &c. to the upper floor. No provision will be made for a patients' hoist, as the staircases are wide and in direct communication from the outside with all the wards. A small room for operations is provided on the ground-floor, on the same level as the accident and surgical wards. The outbuildings consist of a salt-water bath-house, already mentioned, a laundry, and a post-mortem room (to be used as a dissecting-room) with dead-house attached.

French Coast Telegraphic System.—Within the last few years the oceanic coasts of France have been brought into communication, by means of the electric telegraph, with the head-quarters of the four maritime commands established in that portion of the empire; the stations on the coast are also supplied with semaphores, which enable vessels to communicate by means of signals, so that the Minister of Marine is in fact in direct communication, not only with the coast, but with every vessel within signal range. These semaphores are also open to the public, so that the captain of any vessel, inward or outward bound, may send or receive news direct to or from any part of the country. In order to complete the system, however, it will require eighteen submarine cables to be laid down between the mainland and the islands dotted about the coast, and the laying of these is about to be commenced by the vessel especially devoted to that purpose by the Imperial Government, the "Dix Decembre," which has returned from laying the Algerian cable. Amongst the coast cables to be laid immediately is that which is to unite the Isle of Ushant with the ʼnd.

THE RESTORATION OF GUILDHALL, LONDON.

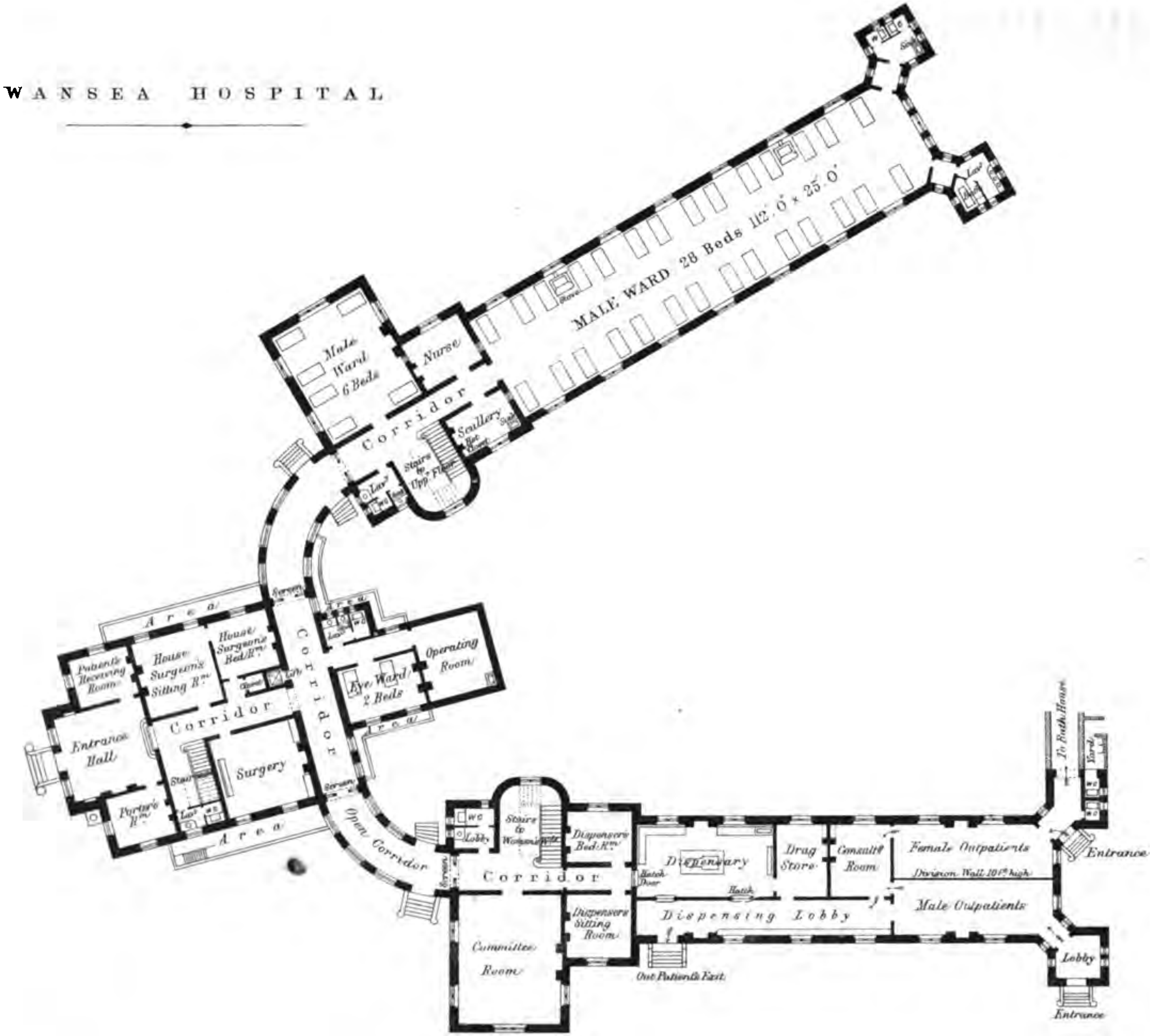
Those who may be entertained in the city of London on Lord Mayor's Day will hardly fail to be greatly struck with the stately appearance which the ancient Guildhall will then present in its restored state, with its grand open roof of oak, resembling that of Westminster-hall, supplanting the flat and unsightly ceiling which had existed since the great fire of London. For more than two years the whole structure has been undergoing a process of thorough restoration, at a cost of between £20,000 and £30,000, under the supervision of a special committee of the Court of Common Council, assisted by Mr. Horace Jones, the city architect, and the works are now being pushed forward with great vigour in anticipation of the banquet on the 9th of November. When we state that the restoration was only undertaken after consultation with Mr. Digby Wyatt and Mr. Edward Roberts, whose advice was sought by the corporation in addition to that of their own architect, Mr. Jones, the strictest archæologist need have no anxiety as to the manner in which the work is being executed. Funds have been from time to time voted for the purpose by the Common Council in the most generous spirit.

The roof has been constructed as nearly as possible in accordance with the period in which the hall itself was originally built, about 450 years ago, and with a drawing, still extant, of the old roof as it existed before its destruction in the great fire of London; a number of windows by which the interior of the building was lighted from the south side, and which had been closed for generations, have been re-opened; and by the removal of an unsightly coating of plaster and cement, all the characteristic outlines of the internal architectural embellishments have been brought prominently out—the general effect being most pleasing to the eye. The new roof is of oak, consisting of eight bays, and with rather a high pitch. It is lighted by sixteen dormers or windows, eight on each side, and from the centre springs a towering spire or louvre, for the purposes of light and ventilation as well as ornament. The erection of a screen at the east end of the hall, with a dais or hustings in carved oak, at an estimated expense together of about £2400, is part of the general scheme of decoration; as is also a raised gallery, corresponding to the ancient minstrel's gallery, which usually occupied a prominent position in similar buildings, at the west end, at a probable cost of £1250, including alterations dependent upon its erection. The turrets, pinnacles, and upper portion of the buttresses are being repaired, at an estimated cost of about £4800. The internal stonework and the tracery of the windows are being repaired and restored at an expense amounting to about £800, and it is in contemplation to substitute marble, purbeck, or serpentine for the present plain painted shafts of the clustered columns, at a further cost of £2000. For the roof alone £5900 has been voted, in addition to sums previously granted for the purpose. At night, at great civic entertainments, the interior of the hall will be lighted by sixteen gaseliers, after a design prepared by the architect. These, with a sun burner under the louvre for purposes of ventilation, are estimated to cost £2250. Regard being had to the monumental character of the hall, the special committee charged with the general work of restoration have recommended the entire pavement of the floor with white stone, with granite or marble bands and black incised lines, the intersections being filled with ornamental brasses, which would afford facilities for warming the interior. The expense of this is estimated at £1870.—*Times.*

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

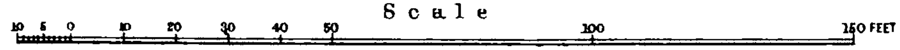
The British Association for the Advancement of Science commenced its thirty-fifth annual meeting, on the 6th ult., at Birmingham. This is the third annual meeting held in Birmingham during the thirty-five years of the existence of the Association. The report showed that the receipts for the past year were £3831, and the expenditure leaves a disposable balance of £759 in the hands of the treasurer. It is gratifying to find that every year appears to bring with it an increased amount of interest in the objects and transactions of the Association. The Birmingham meeting has been a very successful one, and the attendance was greater than on any former occasion. The first general meeting was held in the Town Hall, when Sir Charles Lyell, Bart., formally resigned the Presidential chair to Prof. Phillips, LL.D., F.R.S., who then delivered the inaugural address:—

SWANSEA HOSPITAL



PLAN OF GROUND FLOOR.

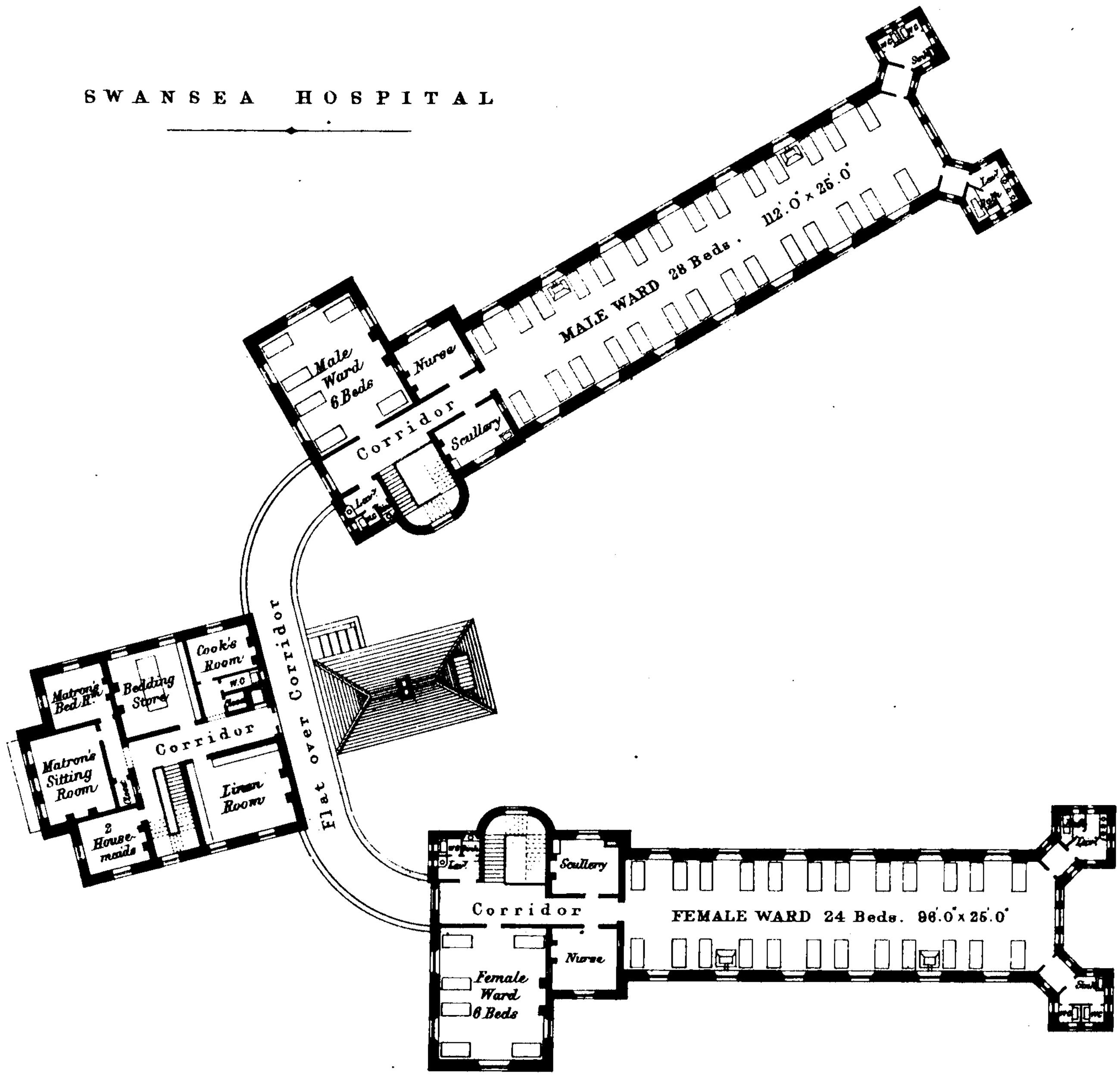
Scale



ALEX GRAHAM, ARCH^T

J R Jobbins

SWANSEA HOSPITAL



PLAN OF FIRST FLOOR.

Scale.

10 5 0 10 20 30 40 50 100 150 FEET

ALEX GRAHAM, ARCHT.

J.R. Jobbins

The President's Address.

Assembled for the third time in this busy centre of industrious England, amid the roar of engines and the clang of hammers, where the strongest powers of nature are trained to work in the fairy chains of art, how softly falls upon the ear the accent of science, the friend of that art, and the guide of that industry! Here, where Priestley analysed the air, and Watt obtained the mastery over steam, it well becomes the students of nature to gather round the standard which they carried so far into the fields of knowledge. And when, on other occasions, we meet in quiet colleges and academic halls, how gladly welcome is the union of fresh discoveries and new inventions with the solid and venerable truths which are there treasured and taught. Long may such union last; the fair alliance of cultivated thought and practical skill; for by it labour is dignified and science fertilised, and the condition of human society exalted!

Through this happy union of science and art, the young life of the British Association—one-third of a century—has been illustrated by discoveries and enriched by useful inventions in a degree never surpassed. How else could we have gained that knowledge of the laws of nature which has added to the working strength of a thousand millions of men the mightier power of steam,* extracted from the buried ruins of primeval forests their treasured elements of heat and light and colour, and brought under the control of the human finger, and converted into a messenger of man's gentlest thoughts, the dangerous mystery of the lightning? †

How many questions have we asked—not always in vain—regarding the constitution of the earth, its history as a planet, its place in creation;—now probing with sharpened eyes the peopled space around—peopled with a thousand times ten thousand stars;—now floating above the clouds in colder and clearer air;—now traversing the polar ice—the desert sand—the virgin forest—the unconquered mountain;—now sounding the depths of the ocean, or diving into the dark places of the earth. Everywhere curiosity, everywhere discovery, everywhere enjoyment, everywhere some useful and therefore some worthy result. Life in every form, of every grade, in every stage; man in every clime and under all conditions; the life that now surrounds us and that which has passed away;—these subjects of high contemplation have been examined often, if not always, in the spirit of that philosophy which is slowly raising, on a broad security of observed facts, sure inductions, and repeated experiments, the steady columns of the temple of physical truth.

Few of the great branches of the study of nature on which modern philosophy is intent were left unconsidered in the schools of Athens; hardly one of them was, or indeed could be, made the subject of accurate experiment. The precious instrument of exact research—the measures of time, and space, and force, and motion—are of very modern date. If instead of the few lenses and mirrors of which traces appear in Greek and Roman writers,‡ there had been even the first Galilean or the smallest Newtonian telescope in the hands of Hipparchus, Eratosthenes, or Ptolemy, would it have been left to their remote successors to be still struggling with the elements of physical astronomy, and waiting with impatience till another quarter of a century shall have rolled away and given us one more good chance of measuring the distance of the sun by the transit of Venus? Had such instruments as Wheatstone's chronoscope been invented, would it have been left to Foucault to condense into his own apartment an experimental proof of the velocity of light, and within a tract of thirty feet to determine the rate of its movement through all the vast planetary space of millions and thousands of millions of miles, more exactly than had been inferred by astronomers from observations of the satellites of Jupiter?§ By this experiment the velocity of light appears to be less, sensibly less, than was previously admitted; and this conclusion is of the highest interest. For, as by assuming too long a radius for the orbit of Jupiter the calculated rate of light-movement was too great; so now, by employing the more exact rate and the same measures of time we can correct the estimated distance of Jupiter and all the other planets from the sun. We have in fact a really independent measure of planetary space; and it concurs with observations of the parallax of Mars in requiring a considerable reduction of the assumed diameters of the planetary paths. The distance of the earth from the sun must be reduced from above ninety-five to less than ninety-three millions of miles, and by this scale the other space-measures of the solar system, excepting the diameter of the earth and the distance and diameter of the moon, may be corrected.*

The light and heat which are emitted from the sun reach the earth without great diminution by the absorptive action of the atmosphere; but the waste of heat from the surface of our planet through radiation into space is prevented, or rather lessened, by this same atmosphere. Many transparent bodies admit freely heat-rays derived from a source of high temperature, but stop the rays which emanate from bodies only slightly warmed. The atmosphere possesses this quality in a remarkable degree, and owes it to the presence of diffused water and vapour; a fact which Dr. Tyndall has placed in the clear light of complete and varied experiment.† The application of this truth to the history of the earth and of the other planets is obvious. The vaporous atmosphere acts like warm clothing to the earth. By an augmented quantity of vapour dissolved, and water suspended in the air, the waste of surface-heat of the earth would be more impeded; the soil, the water, and the lower parts of the atmosphere would grow warmer; the climates would be more equalised; the general conditions more like what has been supposed to be the state of land, sea, and air during the geological period of the Coal-measures.

Such an augmentation of the watery constituents in the atmosphere would be a natural consequence of that greater flow of heat from the interior which by many geologists, mathematicians, and chemists is supposed to have happened in the earlier periods of the history of the earth.

By the same considerations we may understand how the planet Mars, which receives not half so much heat from the sun‡ as the earth does, may yet enjoy, as in fact it seems to enjoy, nearly a similar climate, with snows alternately gathering on one or the other of its poles, and spreading over large spaces around, but not, apparently, beyond the latitude of 50° or 40°; the equatorial band of 30° or 40° north or south being always free from snow-masses bright enough and large enough to catch the eye of the observer. Mars may, therefore, be inhabited, and we may see in the present state of this inquiry reason to pause before refusing the probability of any life to Jupiter and even more distant planets.

The history of suns and planets is in truth the history of the effects of light and heat manifested in them or emanating from them. Nothing in the universe escapes their influence; no part of space is too distant to be penetrated by their energy; no kind of matter is able to resist their transforming agency. Many if not all the special forces which act in the particles of matter are found to be reducible into the general form of heat; as this is convertible and practically is converted into proportionate measures of special energy. Under this comprehensive idea of convertibility of force, familiar to us now by the researches of Joule,§ the reasonings of Grove|| and Helmholtz, and the theorems of Rankine, ¶ it has been attempted by Mayer, Waterston, and

* The quantity of coal dug in Great Britain in the year 1864 appears, by the returns of Mr. R. Hunt, to have been 92,787,873 tons. This would yield, if employed in steam engines of good construction, an amount of available force about equal to that of the whole human race. But in the combustion of coal not less than ten times this amount of force is actually set free—nine-tenths at present being unavailable, according to the statement of Sir William Armstrong, in his address to the meeting at Newcastle in 1863.

† The definite magnetic effect of an electrical current was the discovery of Oersted in 1819; Cooke and Wheatstone's patent for an electric telegraph is dated in 1837; the first message across the Atlantic was delivered in 1858. Tantæ molis erat.

‡ The effect of lenses or globes of glass or crystal in collecting the solar rays to a point are familiarly referred to by Aristophanes in the Nubes, 766; and the ornamental use of convex and concave reflectors is known by the curious discussions in the fourth book of Lucretius.

§ Fizeau performed experiments on the velocity of light between Suresnes and the Butte Montmartre, by means of the oxy-hydrogen light, reflected back in its own path. The space was 28,324 feet, English. Twice this distance was traversed in $\frac{1}{18000}$ of a second=167,528 geogr. miles in a second. From observations of Jupiter's satellites Delambre inferred 167,976 miles, Struve 166,096. The experiment of M. Foucault gives 298,000,000 metres=160,920 geogr. miles.

* Estimates of the earth's distance from the sun have varied much. Cassini and Flamsteed, using observations of the parallax of Mars, ascribe to it ten or eleven thousand diameters of the earth=79 or 89 millions of miles. Huygens estimated it at twelve thousand=95 millions of miles. In 1745, Buffon reported it as the common opinion of astronomers at 30 millions of lieues (Fr.)=90 millions of miles (Engl.), but after the transit of Venus in 1769, he allowed 33 millions. Such was the effect of that now supposed erroneous experiment on the opinions of astronomers. (Epoques de la Nature.)

† Proc. of Roy. Soc. 1861. The Rumford Medal was adjudged to Dr. Tyndall in 1864.

‡ The proportion is about $\frac{100}{231}$ according to the received measures of the mean distance.

§ Phil. Mag. 1843; Reports of the British Association, 1845; Trans. of the Royal Society, 1850.

|| Grove on the Correlation of Physical Forces, 1846.

¶ Rankine, Trans. of the Royal Society of Edinburgh, 1850-1; Phil. Trans. 1854.

Thomson * to assign a cause for the maintenance of the heat-giving power of the sun in the appulse of showers of aërolites and small masses of matter, and the extinction of their motion on the surface of the luminary. By calculations of the same order, depending on the rate of radiation of heat into space, the past antiquity of the earth and the future duration of sunshine have been expressed in thousands or millions of centuries. † In like manner the physical changes on the sun's disc, by which portions of his darkly-heated body become visible through the luminous photosphere, have been connected, if not distinctly as a cause, certainly as a coincident phenomenon, with particular magnetic disturbances on the surface of the earth; the solar spots and the magnetic deflections concurring in periods of maxima and minima of ten or eleven years' duration. Thus even these aberrant phenomena become part of that amazing system of periodical variation which Sabine and his fellow-labourers, British, French, German, Russian, and American, have established by contemporaneous observation over a large part of the globe.‡

With every change in the aspect and position of the sun, with every alteration in the place and attitude of the moon, with every passing hour, the magnetism of the earth submits to regular and calculable deviation. Through the substance of the ground, and across the world of waters, Nature, ever the beneficent guide to science, has conveyed her messages and executed her purposes by the electric current, before the discovery of Oersted and the magical inventions of Wheatstone revealed the secret of her work.'

Even radiant light, in the language of the new philosophy is conceived of by Maxwell,§ as a form of electro-magnetic motion. And thus the imponderable, all-pervading powers, by which molecular energy is excited and exchanged, are gathered into the one idea of restless activity among the particles of matter:—

. . . *æterno percita motu* :

ever-moving and being moved, elements of a system of perpetual change in every part, and constant preservation of the whole.

What message comes to us with the light which springs from the distant stars, and shoots through the depths of space, to fall upon the earth after tens, or hundreds, or thousands of years? It is a message from the very birthplace of light, and tells us what are the elementary substances which have influenced the refraction of the ray. Spectral analysis, that new and powerful instrument of chemical research, for which we are indebted to Kirchhoff, has been taught by our countrymen to scrutinize not only planets and stars, but even to reveal the constitution of the nebulæ, those mysterious masses out of which it has been thought new suns and planets might be evolved—nursing-mothers of the stars. For a time indeed, the resolution of some nebulæ by the giant mirror of Lord Rosse afforded ground for opposing the speculation of Herschel and the reasoning of Laplace, which required for their very starting-point the admission of the existence of thin gaseous expansions, with or without points or centres of incipient condensation, with or without marks of internal movement. The latest results, however, of spectral analysis of stars and nebulæ, by Mr. Huggins and Professor W. A. Miller, have fairly restored the balance. The nebulæ are indeed found to have in some instances stellar points, but they are not stars; the whole resembles an enormous mass of luminous gas, with an interrupted spectrum of three lines, probably agreeing with nitrogen, hydrogen, and a substance at present unknown.|| Stars tested by the same accurate hands are found to have a constitution like that of our own sun, and like it, to show the presence of several terrestrial elements—as sodium, magnesium, iron, and very often hydrogen. While in the Moon and Venus no lines whatever are found due to an atmosphere, in Jupiter and Saturn, besides the lines which are identical with some produced in our own atmosphere, there is one in the red, which may be caused by the presence of some unknown gas or vapour. Mars is still more peculiar, and enough is ascertained to discountenance the notion of his redness being due to a peculiarity of the soil.*

To aid researches into the condition of celestial bodies, the new powers of light, discovered by Niepce, Daguerre, and Talbot, have been employed by Bond, Draper, De la Rue, and other astronomers. To our countryman, in particular, belongs the honour of successful experiments on the rose-coloured flames which extend from certain points of the sun's border during an eclipse; as well as of valuable contributions through the same agency to that enlarged survey of the physical aspect of the moon, which since 1852 the Association has striven to promote. By another application of the same beautiful art, in connection with clock-work, the momentary changes of magnetic force and direction, the variations of temperature, the fluctuations of atmospheric pressure, the force of the wind, the fall of rain, the proportion of ozone in the air, are registered in our observatories; and thus the inventions of Ronalds and his successors have engaged the solar rays in measuring and comparing contemporaneous phenomena of the same order over large parts of the globe—phenomena some of which are occasioned by those very rays.

As we ascend above the earth, heat, moisture, and magnetic force decrease, the velocity of wind augments, and the proportion of oxygen and nitrogen remains the same. The decrease of heat as we rise into the air is no new subject of inquiry, nor have the views respecting it been very limited or very accordant. Leslie considered it mathematically in relation to pressure; Humboldt gave the result of a large inquiry at points on the earth's surface unequally elevated above the sea; and finally, Mr. Glaisher and Mr. Coxwell, during many balloon ascents to the zones of life-destroying cold, far above our mountain tops, have obtained innumerable data, in all seasons of the year, through a vast range of vertical height. The result is to show much more rapid decrease near the earth, much slower decrease at great elevations; thus agreeing in general with the view of Leslie, and yet throwing no discredit on the determinations of Humboldt, which do not refer to the free atmospheric ocean, but to the mere borders of it where it touches the earth, and is influenced thereby. †

The proportion of carbonic acid gas in the atmosphere at great heights is not yet ascertained: it is not likely to be the same as that generally found near the earth; but its proportion may be more constant, since in those regions it is exempt from the influence of the actions and re-actions which are always in progress on the land and in the water, and do not necessarily compensate one another at every place and at every moment.

Other information bearing on the constitution of the atmosphere comes to us from the auroral beams and other meteoric lights known as shooting stars. For some of these objects not only appear at heights of 10, 50, and 100 or more miles above the earth, but at the height of 50 miles it is on record that shooting stars or fire-balls have left waving trains of light, whose changes of form were in seeming accordance to varying pressure in the elevated and attenuated atmosphere.‡

Researches of every kind have so enriched meteorology since our early friend, Professor J. Forbes, printed his suggestive reports on that subject; and so great have been the benefits conferred on it by the electric telegraph, that at this moment, in M. Leverrier's observatory at Paris, and the office so lately presided over by Admiral Fitzroy in London, the messages are arriving from all parts of Europe to declare the present weather, and furnish grounds for reasonable expectation of the next probable change. Hardly now within the seas of Europe can a cyclone begin its career of devastation, before the warning signal is raised in our sea-ports to restrain the too confident sailor. The gentle spirit which employed this knowledge in the cause of humanity has passed away, leaving an example of unselfish devotion in a work which must not fail through any lack of energy on the part of this Association, the Royal Society, or the Government. We must extend these researches and enlarge these benefits, by the aid of the telegraph bringing the ends of the world together. Soon may that thread of communication unite the two great sections of the Anglo-Saxon race, and

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* Communication to the Royal Society of Edinburgh, 1854.

† Professor Thomson assigns to the sun's heat, supposing it to be maintained by the appulse of masses of matter, a limit of 300,000 years; and to the period of cooling of the earth from universal fusion to its actual state, 98,000,000 years. These are the lowest estimates sanctioned by any mathematician.

‡ Among the interesting researches which have been undertaken on the subject of the spots, may be mentioned those of Wolf (Comptes Rendus, 1859), who finds the number and periodicity of the spots to be dependent on the position of Venus, the Earth, Jupiter, and Saturn. Stewart has made a special study of the relation of the spots to the path of Venus (Proc. of the Roy. Soc. 1864); and Chacornac is now engaged in unfolding his conception of the spots as the visible effect of volcanic excitement. The peculiar features of the solar surface are under examination by these and other good observers; such as Dawes, Nasmyth, Secchi, Stone, Fletcher, and Lockyer.

§ Proc. of Roy. Soc. 1864. The elder Herschel appears to have regarded the light of the sun and of the fixed stars as perhaps the effect of an electro-magnetic process—a perpetual aurora.

|| Proc. Roy. Soc. and Phil. Trans. 1864.

* Phil. Trans. 1864.

† Reports of the British Association for 1862, 1863, 1864.

‡ This is the result of a careful discussion made by myself of observations on a meteor seen from Rouen to Yorkshire, and from Cornwall to Kent, Jan. 7, 1856.

bring and return through the broad Atlantic the happy and mutual congratulations for peace restored and friendships renewed!

The possible combinations of force, by which in the view we have been considering the characteristic forms and special phenomena of solid, liquid, and gaseous matter are determined, may be innumerable. Practically, however, they appear to be limited, as natural products, to less than one thousand distinguishable compounds, and less than one hundred* elementary substances. Of these elements the most prevalent are few on the earth; as of gases, oxygen, hydrogen, nitrogen; of solids, silicon, calcium, magnesium, sodium, iron, and it is interesting to learn by analysis of the light of stars and planets, that these substances, or some of them, are found in most of the celestial objects yet examined, and that, except in one or two instances, no other substances have been traced therein. Even the wandering meteoric stones, which fall from their courses, and are examined on the earth, betray only well-known mineral elements, though in the manner in which these are combined some differences appear, which by chemical research and the aid of transparent sections Professor Maskelyne and Mr. Sorby are engaged in studying and interpreting.†

By the labours of Lavoisier and his contemporaries chemistry acquired a fixed logic and an accurate nomenclature. Dalton and the great physicists of the early part of this century gave that law of definite combination by proportionate weights of the elements which is for chemistry what the law of gravitation is for celestial mechanics. A great expansion of the meaning of the atomic theory took place when Mitscherlich announced his views of isomorphous, isomeric, and dimorphous bodies. For thus it came gradually to appear that particular forces resided in crystals in virtue of their structure, lay in certain directions, and exhibited definite physical effects, if the chemical elements, without being the same, were combined in similar proportions, and aggregated into similar crystals. Some years later ozone was discovered by Schönbein, and it concurred with a few other allotropic substances in reviving, among philosophic chemists, the inquiry as to the relative situation of the particles in a compound body, and the effects of such arrangements: an idea which had been expressed by Dalton in diagrams of atoms, and afterwards exercised the ingenuity of Exley, MacVicar, and others.‡

Everything connected with this view of the modification of physical properties by the arrangement of the particles—whether elementary or compound—is of the highest importance to mineralogy, a branch of study by no means so much in favour even with chemists as its own merits and its collateral bearings might justly deserve. Yet it is in a great measure by help of this branch of study that the opinions now current regarding metamorphism of rocks *in situ*, and the formation of mineral veins, must acquire that solid support and general consent which at present they do not possess. Crystals, indeed, whether regarded as to their origin in nature, their fabrication by art, or their action on the rays of light, the waves of heat and sound, and the distribution of electricity, have not been neglected by the Association or its members. In one of the earliest reports, Dr. Whewell calls attention to the state of crystallographical theory, and to the artificial production of crystals; and in another report Professor Johnston notices epigene and pseudomorphous crystallisation; and for many years, at almost every meeting, new and brilliant discoveries in the action of crystals on light were made known by Brewster,§ and compared with the undulatory theory by Herschel, MacCullagh, Airy, Hamilton, Whewell, Powell, Challis, Lloyd, and Stokes.

The unequal expansion of crystals by heat, in different directions, first observed by Mitscherlich, has been carefully examined in the cases of sulphate and carbonate of lime by Professor W. H. Miller, who had also considered their elasticity, originally measured in different relations to the axis by Savart. These and many other interesting relations of crystals have been attended to, but the Association has not yet succeeded in obtaining a complete digest of the facts and theories connected with the appearance of crystals in nature—in the fissures of rocks; in the smaller cavities of rocks; in the solid substance or liquid contents of other crystals. Such an inquiry, however, it did earnestly demand, and some steps have been taken by our own chemists, mineralogists, and geologists. But more abundant information on this class of subjects is still needed, even after the admirable contributions and recent discoveries of Bischof, Delesse, and Daubrée.

Within our Association period both the nomenclature of chemistry and the conception of the atomic theory have received, not indeed a change, but such an addition to its ordinary expression, as the more general language and larger meaning of algebra have conferred on common arithmetical values. The theory of compound radicals, as these views of Liebig, Dumas, and Hoffman may be justly termed, embraces the consideration of groups of elements united in pairs by the ordinary law, these groups being for the purpose in hand treated as single elements of combination. The nomenclature which attempts in ordinary words to express these relations grows very unmanageable even in languages more easily capable of polysyllabic combinations than ours; but symbols of composition—the true language of chemistry—are no more embarrassed in the expression of these new ideas than are the mathematical symbols which deal with operations of much greater complexity on quantities more various and more variable. The study of these compound radicals comes in aid of experimental research into those numerous and complex substances which appear as the result of chemical transformations in organic bodies. Thus in some instances the very substances have been recomposed by art which the vital processes are every moment producing in nature; in others the steps of the process are clearly traced; in all the changes become better understood through which so great a variety of substances and structures are yielded by one circulating fluid; and the result is almost a new branch of animal and vegetable physiology, not less important for the health of mankind than essential to the progress of scientific agriculture,

The greater our progress in the study of the economy of nature, the more she unveils herself as one vast whole, one comprehensive plan, one universal rule, in a yet unexhausted series of individual peculiarities. Such is the aspect of this moving, working, living system of force and law: such it has ever been, if we rightly interpret the history of our own portion of this rich inheritance of mind, the history of that Earth from which we spring, with which so many of our thoughts are co-ordinated, and to which all but our thoughts and hopes will again return.

How should we prize this history! and exult in the thought that in our own days, within our own memories, the very foundations of the series of strata, deposited in the beginning of time, have been explored by our living friends, our Murchison and Sedgwick, while the higher and more complicated parts of the structure have been minutely examined by our Lyell, Forbes, and Prestwich!* How instructive the history of that long series of inhabitants which received in primeval times the gift of life, and filled the land, sea, and air with rejoicing myriads, through innumerable revolutions of the planet, before in the fulness of time it pleased the Giver of all good to place man upon the earth, and bid him look up to heaven.

Wave succeeding wave, the forms of ancient life sweep across the ever-changing surface of the earth: revealing to us the height of the land, the depth of the sea, the quality of the air, the course of the rivers, the extent of the forest, the system of life and death—yes, the growth, decay, and death of individuals, the beginning and ending of races, of many successive races of plants and animals, in seas now dried, on sand-banks now raised into mountains, on continents now sunk beneath the waters.

Had that series a beginning? Was the earth ever uninhabited after it became a globe turning on its axis and revolving round the sun? Was there ever a period since land and sea were separated—a period which we can trace—when the land was not shaded by plants, the ocean not alive with animals? The answer, as it comes to us from the latest observation, declares that in the

* At the present moment the number of elementary substances is sixty-one.

† Professor Maskelyne has made a convenient classification of the large collection of meteorites in the British Museum, under the titles of "Aërolite or Meteoric Stone;" "Aërosiderite or Meteoric Iron;" and "Aërosiderolites," which includes the intervening varieties. Mr. Sorby, whose latest results are unpublished, but will be communicated to the Royal Society, is of opinion that the substance of meteorites has undergone changes due to physical conditions in some ancient period not now to be paralleled on our planet, or on the moon, but rather to be looked for only in the immediate neighbourhood of the sun. Professor Haidinger has also made a special study of meteorites.

‡ Dalton, Chemistry, vol. i. 1808. A clear view of the simpler applications of Dalton's ideas is given by the illustrious author in Daubeny's Treatise on the Atomic Theory, 1850. Exley, Nat. and Exp. Philosophy, 1829. MacVicar, Reports of the British Association for 1855.

§ "Sir David Brewster must be considered as in a degree the creator of the science which studies the mutual dependence of optical properties and crystalline forms." (Whewell, in Report on Mineralogy, Brit. Association, 1832, p. 336.)

* The investigations of Murchison and Sedgwick in the Cambrian and Silurian strata began in 1831; the views of Sir C. Lyell on Tertiary periods were made known in 1829.

lowest deposits of the most ancient seas in the stratified crust of the globe, the monuments of life remain. They extend to the earliest sediments of water, now in part so changed as to appear like the products of fire. What life? Only the simpler and less specially organized fabrics have as yet rewarded research among these old Laurentian rocks—only the aggregated structures of Foraminifera have been found in what, for the present at least, must be accepted as the first deposits of the oldest sea. The most ancient of all known fossils, the Eozoon Canadense of Sir W. Logan, is of this low, we may even say lowest, type of animal organization.

Then step by step we are guided through the old Cambrian and Silurian systems, rich in Trilobites and Brachiopoda, the delights of Salter and Davidson; with Agassiz and Miller and Egerton we read the history of the strange old fishes of the Devonian rocks; Brongniart and Göppert, and Dawson, and Binney, and Hooker, unveil the mystery of the mighty forests now converted to coal; Mantell and Owen and Huxley restore for us the giant reptiles of the Lias, the Oolite, and the Wealden; Edwards and Wright almost revive the beauteous corals and echinodermata; which with all the preceding tribes have come and gone before the dawn of the later periods, when fragments of mammoths and hippopotami were buried in caves and river sediments, to reward the researches of Cuvier and Buckland, Prestwich and Christy, Lartet and Falconer.

And what is the latest term in this long series of successive existence? Surely the monuments of ever-advancing art—the temples whose origin is in caverns of the rocks; the cities which have taken the place of holes in the ground, or heaps of stones and timber in a lake; the ships which have outgrown the canoe, as *that* was modelled from the floating trunk of a tree, are sufficient proof of the late arrival of man upon the earth, after it had undergone many changes and had become adapted to his physical, intellectual, and moral nature.

Compared with the periods which elapsed in the accomplishment of these changes, how short is the date of those yet standing monoliths, cromlechs, and circles of unhewn stone, which are the oldest of human structures raised in Western Europe, or of those more regular fabrics which attest the early importance of the monarchs and people of Egypt, Assyria, and some parts of America! Yet, tried by monuments of natural events which happened within the age of man, the human family is old enough in Western Europe to have been sheltered by caverns in the rocks, while herds of reindeer roamed in Southern France,* and bears and hyænas were denizens of the South of England.† More than this, remains of the rudest human art ever seen are certainly found buried with and are thought to belong to races who lived contemporaneously with the mammoth and rhinoceros, and experienced the cold of a Gallic or British winter, from which the woolly covering of the wild animals was a fitting protection.

Our own annals begin with the Kelts, if indeed we are entitled to call by that historic name the really separate nations, Belgian, Iberian, and Teutonic, whom the Roman writers recognise as settlers in Britain;‡ settlers among a really earlier family, our rudest and oldest forefathers, who may have been, as they thought themselves to be, the primitive people of the land.§ But beyond the Κελται who occupied the sources of the Danube and the slopes of the Pyrenees, and were known to Rome in earlier days, there was present to the mind of the father of Grecian history a still more western race, the Cynetæ, who may perhaps be supposed the very earliest people of the extreme west of the continent of Europe. Were those the people, the first poor pilgrims from the East, whose footsteps we are slowly tracing in the valleys of Picardy and the South of England, if not on the borders of the lakes of Switzerland? Are their kindred still to be found among the Rhætic Alps and the Asturian cliffs, if not amid the wilds of Connemara, pressed into those mountainous recesses by the legions of Rome, the spear of the Visigoth, and the sword of the Saxon? Or must we regard them as races of an earlier type, who had ceased to chip flints before the arrival of Saxon, or Goth, or Kelt, or Cynetian? These questions of romantic interest in the study of the distribution and languages of the families of man are part of a large circle of inquiry which finds sympathy in several of our sections, especially those devoted to zoology, physiology, and ethnology. Let us not expect or desire for them a very quick, or at present a very definite settlement. Deep shadows have gathered over all the earlier ages of mankind, which perhaps still longer periods of time may not avail to remove. Yet let us not undervalue the progress of ethnological inquiry, nor fail to mark how, within the period to which our recollections cling, the revelations of early Egypt have been followed by a chronology of the ancient kingdoms on the Tigris and Euphrates, through the same rigorous study of language. Thus has our Rawlinson added another page to the brilliant discoveries of Young and Champollion, Lepsius and Rosellini.

Nor, though obtained in a different way, must we forget the new knowledge of a people nearer home which the philosophic mind of Keller has opened to us among his native mountains. There, on the borders of the Alpine lakes, before the great Roman general crossed the Rhone, lived a people older than the Helvetians, whose rude lives, passed in hunting and fishing, were nevertheless marked by some of the many inventions which everywhere, even in the most unfavourable situations, accompany the least civilised of mankind. Implements of stone and pottery of the rudest sort belong to the earliest of these people; while ornamented iron weapons of war, and innumerable other fabrics in that metal, appear about the later habitations, and correspond probably to the period of the true Helvetii, who quitted their home and contended with Cæsar for richer settlements in Gaul. The people of whom these are the traces on almost every lake in Switzerland are recognised as well in the ancient lake-basins of Lombardy and among Tyrolean Alps, and farther on the north side of the mountains; and probably fresh discoveries may connect them with the country of the Sarmatians and the Scythians.

Thus at length is fairly opened, for archæology and palæontology to read, a new chapter of the world's history, which begins in the pleistocene periods of geology, and reaches to the prehistoric ages of man. Did our ancestors really contend, as the poets fancied, with stones and clubs against the lion and the rhinoceros, and thus expel them from their native haunts; or have they been removed by change of climate or local physical conditions? Was the existence of the hyæna and the elephant only possible in Western Europe while a climate prevailed there such as now belongs to Africa or India? and was this period of high temperature reduced in a later time for the elk, reindeer, and musk ox, which undoubtedly roamed over the hills of England and France? If we think so, what a vista of long duration stretches before us, for no such changes of climate can be supposed to have occurred except as the effect of great physical changes, requiring a lapse of many thousands of years. And though we may think such changes of climate not proved, and probably careful weighing of evidence may justify our disbelief, still, if the valleys in Picardy have been excavated since the deposit of the gravel of St. Acheul, and the whole face of the country has been altered about the caverns of Torquay since they received remains of animals and traces of man—how can we admit these facts and yet refuse the time required for their accomplishment! First, let us be sure of the facts, and especially of that main fact upon which all the argument involving immensity of time really turns, viz. the contemporaneous existence of man with the mammoth of the plains and the bear of the caverns. The remains of men are certainly *buried* with those of extinct quadrupeds; but did they *live* in the same days, or do we see relics of different periods gathered into one locality by natural processes of a later date, or confused by the operations of men?

Before replying finally to these questions, further researches of an exact kind are desirable, and the Association has given its aid towards them, both in respect to the old cavern of Kent's Hole, and the newly opened fissure of Gibraltar, from which we expect great results, though the best of our labourers has ceased from his honourable toil.* When these and many other researches are completed, some future Lyell, if not our own great geologist, may add some fresh chapters to the 'Antiquity of Man.'

In judging of this antiquity, in counting the centuries which may have elapsed since smoothed flints fitted with handles of wood were used as chisels and axes by the earliest people of Scandinavia or Helvetia, and flakes of flint were employed to cleanse the skins of the reindeer in the caves of the Dordogne,

* See the Memoirs of M. Lartet on the Caves of the Dordogne, 1863-4.

† In the caves of Gower, Devon, and Somerset, flint flakes occur with several extinct animals.

‡ Gallic or Belgian on the south-east coast; Iberian in South Wales; German at the foot of the Grampians.—(Tacitus, Vita Agricolæ.)

§ "Britanniciæ pars interior ab iis incolitur, quos natos in insula ipsa memoria proditum dicunt."—(Cæsar, v. 12.)

* The late Dr. Hugh Falconer, whose knowledge of the fossil animals of caves was remarkably exact, took a great share in these examinations.

or stronger tools broke up the ice in the valley of the Somme, we must be careful not to take what is the mark of low civilization for the indication of very remote time. In every country, among every race of men, such rude weapons and tools are used now, or were used formerly. On the banks of the Ohio, no less than on the English hills, mounds of earth, rude pottery, and stone weapons occur in abundance, and indicate similar wants, contrivances, customs, ideas, in different races of men living in different periods. Even when in the same country, as in Switzerland, or England, or Denmark, successive deposits of instruments of stone, bronze, or iron; successive burials of pines, beeches, and oaks; successively extinguished races of elephants, elks, and reindeer, give us a real scale of elapsed time, it is one of which the divisions are not yet valued in years or centuries of years.

Toward a right judgment of the length of this scale of human occupation, two other lines of evidence may be thought worthy of notice: one founded on the anatomical study of the remains of early men, the other on the laws of language. If the varieties of physical structure in man, and the deviations of language from an original type, be natural effects of time and circumstance, the length of time may be in some degree estimated by the amount of the diversities which are observed to have happened, compared with the variation which is now known to be happening. This process becomes imaginary, unless we assume all mankind to have had one local centre, and one original language. Its results must be erroneous, unless we take fully into account the superior fixity of languages which are represented in writing, and the greater tendency to diversity of every kind which must have prevailed in early times when geographical impediments were aggravated by dissocial habits of life. It appears however certain that some differences of language, organization, and habits have separated men of apparently unlike races during periods longer than those which rest on historical facts.*

Ever since the days of Aristotle, the analogy existing among all parts of the animal kingdom, and in a general sense we may say among all the forms of life, has become more and more the subject of special study. Related as all living beings are to the element in which they move and breathe, to the mechanical energies of nature which they employ or resist, and to the molecular forces which penetrate and transform them, some general conformity of structure, some frequently recurring resemblance of function, must be present, and cannot be overlooked. In the several classes this analogy grows stronger, and in the subdivisions of these classes real family affinity is recognised. In the smallest divisions which have this family relation in the highest degree there seems to be a line which circumscribes each group, within which variations occur, from food, exercise, climate, and transmitted peculiarities. Often one specific group approaches another, or several others, and a question arises whether, though now distinct, or rather distinguishable, they always have been so from their beginning, or will be always so until their disappearance.

Whether what we call species are so many original creations or derivations from a few types or one type, is discussed at length in the elegant treatise of Darwin, himself a naturalist of eminent rank. It had been often discussed before. Nor will any one think lightly of such inquiries, who remembers the essay of Linnæus, 'De Telluris orbis incremento,' or the investigations of Brown, Prichard, Forbes, Agassiz, and Hooker regarding the local origin of different species, genera, and families of plants and animals, both on the land and in the sea. Still less will he be disposed to undervalue its importance, when he reflects on the many successive races of living forms more or less resembling our existing quadrupeds, reptiles, fishes, and mollusca, which appear to have occupied definite and different parts of the depths of ancient time; as now the tiger and the jaguar, the cayman and the gavial, live on different parts of the terrestrial surface. Is the living elephant of Ceylon the lineal descendant of that mammoth which roamed over Siberia and Europe and North America, or one of those sub-Himalayan tribes which Dr. Falconer has made known, or was it a species dwelling only in circumpolar regions? Can our domestic cattle, horses and dogs, our beasts of chase and our beasts of prey, be traced back to their source in older types, contemporaries of the urus, megaceros, and hyæna on the plains of Europe? If so, what range of variation in structure does it indicate? If not so, by what characters are the living races separated from those of earlier date?

* Max Müller on the Science of Language.

Specific questions of this kind must be answered, before the general proposition, that the forms of life are indefinitely variable with time and circumstance, can be even examined by the light of adequate evidence. That such evidence will be gathered and rightly interpreted, I for one neither doubt nor fear; nor will any be too hasty in adopting extreme opinions, or too fearful of the final result, who remember how often that which is true has been found very different from that which was plausible, and how often out of the nettles of danger we have plucked the flowers of safety. At the present moment the three propositions which were ever present to the mind of Edward Forbes may be successfully maintained, as agreeing with many observed phenomena; and around them as a basis of classification may be gathered most of the facts and most of the speculations which relate to the history of life.* First, it may be admitted that plants and animals form many natural groups, the members of which have several common characters, and are parted from other groups by a real boundary line, or rather unoccupied space. Next, that each of these groups has a limited distribution in space, often restrained by high mountains or deep seas, or parallels of temperature, within which it has been brought into being. Thirdly, that each group has been submitted to, or is now undergoing, the pressure of a general law, by which its duration is limited in geological time; the same group never reappearing after being removed from the series.

How important, in the view of this and many other questions, is that never-tiring spirit of geographical and maritime discovery to which, through four hundred years, Europe has sent her noblest sons and her most famous expeditions; sent them, alas! too often to an early grave. Alas! for Franklin, who carried the magnetic flag into the Icy Sea from which he had already brought trophies to science! Alas! for Speke, who came home with honour from the head-waters of the Nile! Forgotten they can never be; whenever, on occasions like this, we mourn the absence of our bravest and our best; praise, never ending praise be theirs, while men retain the generous impulse which prompts them to enterprises worthy of their country and beneficial to mankind!

'Αει σφων κλεος εσσεται κατ' αιαν.

If it be asked, What share in the discoveries and inventions of the last thirty-three years is claimed for the British Association? let us answer fearlessly—We had a part in all. In some of them we took the foremost place by the frequency of our discussions, the urgency of our recommendations, the employment of our influence, and the grant of our funds. For others we gave all our strength, to support the Royal Society and other institutions in their efforts to accomplish purposes which we approve. In all instances our elastic system responds quickly to pressure, and returns the friendly impulse. If we look back on the work of previous years, it is easy to mark the special action of the Association in fields which hardly could be entered by any other adventurers.

Many of the most valuable labours of which we are now reaping the fruits, were undertaken in consequence of the reports on special branches of science which appear in the early volumes of our Transactions—reports in which particular data were requested for confirming or correcting known generalizations, or for establishing new ones. Thus, a passage in Professor Airy's report on Physical Astronomy† first turned the attention of Adams to the mathematical vision of Neptune; Lubbock's Report on Tides came before the experimental researches and reductions which, since 1834, have so often engaged the attention of Whewell and Airy and Haughton, with results so valuable and so suggestive of further undertakings. Among these results may be placed additional knowledge of the probable depth of the channels of the sea. For before the desire of telegraphic communication with America had caused the bed of the North Atlantic to be explored by soundings to a depth seldom exceeding three miles, there was reason to conclude from the investigations of Whewell on Cotidal Lines that a depth of nine miles was attained in the South Atlantic, and from the separate computations of Airy and Haughton that a somewhat greater depth occurred

* See the remarkable Essay of E. Forbes on the distribution of the existing Fauna and Flora of the British Isles, in Memoirs of Geol. Survey of Britain, vol. 1, p. 336.

† Reports of the British Association for 1832, p. 154. Laplace had indeed observed that "the planet Uranus and his satellites, lately discovered, give reason to suspect the existence of some planets not yet observed;" thereby encouraging the search for new discoveries in our own system. (Exp. du Syst. du Monde, 1799, 4to. p. 350.)

in a part of the course of the tide-wave which washes the coast of Ireland. The greater portion of the sea-bed is within reach of soundings directed by the superior skill and greater perseverance of modern scientific navigators; a depth of six miles is said to have been reached in one small tract of the North Atlantic; depths of nine or ten miles in the deepest channels of the sea are probable from considering the general proportion which is likely to obtain between sea-depths and mountain-tops. Thus the data are gradually being collected for a complete survey of the bed of the sea, including among other things information, at least, concerning the distribution of animal and vegetable life beneath the waters.

Waves—their origin, the mechanism of their motion, their velocity, their elevation, the resistance they offer to vessels of given form, these subjects have been firmly kept in view by the Association, since first Professor Challis reported on the mathematical problems they suggest, and Sir J. Robison and Mr. Scott Russell undertook to study them experimentally. Out of this inquiry has come a better knowledge of the forms which ought to be given to the "lines" of ships, followed by swifter passages across the sea, both by sailing vessels and steamers, of larger size and greater lengths than were ever tried before.

One of the earliest subjects to acquire importance in our thoughts was the unexplored region of meteorology laid open in Professor J. Forbes' Reports. Several of the points to which he called attention have been successfully attained. The admirable instruments of Whewell, Osler, and Robinson have replaced the older and ruder anemometers; and are everywhere in full operation, to record the momentary variations of pressure or sum the varying velocities of the wind. No small thanks were due to Mr. Marshall and Mr. Miller for their enterprise and perseverance, in placing rain gauges and thermometers amidst the peaks of Cumberland and Westmoreland. These experiments are now renewed in both counties and in North Wales; and I hope to hear of similar efforts among the mountains of the West of Ireland and the West of Scotland. Our meteorological instruments of every kind have been improved; our system of photographic registration has spread from Kew into other observatories; and our corresponding member, Professor Dovè, has collected into systematic maps and tables the lines and figures which represent annual and monthly climate over every land and sea.

In the same manner, by no sudden impulse or accidental circumstance, rose to its high importance that great system of magnetic observations on which for more than a quarter of a century the British Association and the Royal Society, acting in concert, have been intent. First, we had reports on the mathematical theory and experimental researches of magnetism, by Christie, 1833, Whewell, 1835, and Sabine, 1835; afterwards a magnetic survey of the British Islands;* then the establishment of a complete observatory at Dublin, with newly arranged instruments, by Dr. Lloyd, in 1838. On all this gathered experience we founded a memorial to Her Majesty's Government, made a grant of £400 from our funds for preliminary expenses, and presented to the meeting of this association in Birmingham, in 1839, a report of progress, signed by Herschel and Lloyd. From that time how great the labour, how inestimable the fruits! Ross sails to the magnetic pole of the South; America and Russia co-operate with our observers at Kew, Toronto, and St. Helena; and General Sabine, by combining all this united labour, has the happiness of seeing results established of which no man dreamed—laws of harmonious variation affecting the magnetic elements of the globe, in definite relation to the earth's movement, the position of the sun and moon, the distribution of temperature, and the situation in latitude and longitude.

Our efforts have not been fruitless, whether with Mr. Mallet we make experiments on artificial earth-shocks at Dalkey, or survey the devastations round Vesuvius, or tabulate the records of earthquakes since the beginning of history; or establish the Kew Observatory as a scientific workshop, where new instruments of research are made and proved and set to work; or dredge the sea with Forbes, and Brady, and Jeffreys; or catalogue the stars with Baily; or investigate electricity with Harris, Ronalds, Thomson, and Jenkin; or try the action of long-continued heat with Harcourt: in these and a hundred other directions our attempts to gain knowledge have brought back new facts and new laws of phenomena, or better instruments for attaining or better methods for interpreting them. Even when we enter the domain of practical art, and apply scientific methods to test a great process of manufacture, we do not fail of success; because we are able to join in united exertion the laborious cultivators of science and the scientific employers of labour.

Am I asked to give an example? Let it be Iron, the one substance by the possession of which, by the true knowledge and right use of which, more than by any other thing, our national greatness is supported. What are the ores of iron—what the peculiarities and improvements of the smelting processes—what the quality of the iron—its chemical composition—its strength in columns and girders as cast-iron; in rails and boiler plate, in tubes and chains, as wrought-iron—what are the best forms in which to employ it, the best methods of preserving it from decay; —these and many other questions are answered by many special reports in our volumes, bearing the names of Barlow, Mallet, Porter, Fairbairn, Bunsen, Playfair, Percy, Budd, Hodgkinson, Thomson; and very numerous other communications from Lucas, Fairbairn, Cooper, Nicholson, Price, Crane, Hartley, Davey, Mushet, Hawkes, Penny, Scoresby, Dawes, Calvert, Clark, Cox, Hodgkinson, May, Schafhaeutl, Johnston, Clay, and Boutigny. Beyond a question, a reader of such of these valuable documents as relate to the strength of iron in its various forms would be far better informed of the right course to be followed in experiments on armour-plated ships and forts to resist assault, and in the construction of ordnance to attack them, than he is likely to be from merely witnessing a thousand trials of the cannon against the target. Anyone who remembers what the iron furnace was forty years ago, and knows its present power of work; or who contrasts the rolling mills and hammers of other days, with the beautiful machines which now, with the gentlest motion but irresistible force, compel the strong metal to take up the most delicately moulded form; will acknowledge that within the period since the British Association began to set itself to the task of reconciling the separated powers of Theory and Experience, there has been a total change in the aspect of each, to the great advantage of both.

Our undertakings have not been fruitless. We attempted what we had well considered, and had the power to accomplish; and we had the more than willing help of competent persons of our own body, the friendly aid of other institutions, and the sanction of the Government, convinced of the sincerity of our purpose and the wisdom of our recommendations.

The same work is ever before us; the same prudence is always necessary; the same aid is always ready. Great indeed should be our happiness on reflecting on the many occasions when the Royal Society in particular, and other institutions older than our own, have readily placed themselves by our side, to share our responsibility and diminish our difficulties. But for this, our wishes might not always have prevailed; and the horizon of science would not have been so clear as now it is. Of late years indeed, societies formed on our model have taken up special parts of our work; and thus to some extent have relieved us of the pressure of communications relating to the practice of particular professions and the progress of some public questions. Not that scientific agriculture, social statistics, or physiology are neglected in our meetings, but that these and other practical subjects are found to have more than one aspect, and to require more than one mode of treatment. With us, facts well ascertained, conclusions rightly drawn, will ever be welcome, from whatever quarter of the horizon of science they make their appearance. Whatever societies cultivate these objects, they are our allies, and we will help them, if we may. With pleasure we receive proofs of the good work done in limited districts by the many admirable Field Clubs formed by our countrymen; whether, like those of Tyne-side and the Cotswolds, and in this immediate vicinity those of Warwickshire, Worcestershire, and Dudley, they explore the minutest recesses of our hills and glens; or, like the rangers of the Alps, bring us new facts regarding glaciers, ancient climate, and altered levels of land and sea.

By these agreeable gatherings natural history is most favourably commended; and in the activity and enlarged views of the officers who conduct them the British Association recognises the qualities by which the vitality of scientific research is maintained, and its benefits diffused among the provincial institutions of the Empire.

Such are some of the thoughts which fill the minds of those who, like our Brewster, and Harcourt, and Forbes,

* The survey was begun in Ireland in 1835, by Lloyd, Sabine, and Ross; and completed in England, Wales, and Scotland in 1837, by the same magneticians, assisted by Fox and Phillips. It was repeated in 1857 and following years by Sabine Lloyd, Welsh, Haughton, Galbraith, and Stoney.

and Murchison, and Daubeny, stood, anxious but hopeful, by the cradle of this British Association, and who now meet to judge of its strength, and measure its progress. When, more than thirty years ago, this parliament of science came into being, its first child-language was employed to ask questions of nature; now, in riper years, it founds on the answers received further and more definite inquiries directed to the same prolific source of useful knowledge. Of researches in science completed, in progress, or in beginning, each of our annual volumes contains some three hundred or more passing notices or full and permanent records. This digest and monument of our labours is indeed in some respects incomplete, since it does not always contain the narrative or the result of undertakings which we started, or fostered, or sustained; and I own to having experienced on this account once or twice a feeling of regret. But the regret was soon lost in the gratification of knowing that other and equally beneficial channels of publication had been found; and that by these examples it was proved how truly the Association kept to the real purpose of its foundation, "the Advancement of Science," and how heartily it rejoiced in this advancement without looking too closely to its own share in the triumph. Here, indeed, is the stronghold of the British Association. Wherever and by whatever means sound learning and useful knowledge are advanced, there to us are friends. Whoever is privileged to step beyond his fellows on the road of scientific discovery will receive our applause, and if need be our help. Welcoming and joining in the labour of all, we shall keep our place among those who clear the roads and remove the obstacles from the paths of science; and whatever be our own success in the rich fields which lie before us, however little we may now know, we shall prove, that in this our day we knew at least the value of knowledge, and joined hearts and hands in the endeavour to promote it.

THE RELATIVE ADVANTAGES OF THE INCH AND THE METRE AS THE STANDARD UNIT OF DECIMAL MEASURE.*

By John Fernie.

The subject of a decimal system of measure resolves itself into two distinct questions: the desirability of a decimal system, and the standard of measure to be adopted as the unit of the decimal system.

The principle of a decimal system of measurement is now considered to be so advantageous and desirable by the practical and scientific men who have entered into the subject, that sooner or later the irregular and inconvenient system hitherto used in this country must be expected to give place to one more suited to the present times. The permissive bill of 1864, which legalised by Act of Parliament the use in this country of the present standards of measure decimalised, and also of the French standard, the metre, is the first public step in that direction; and consequently the question as to which standard is to be finally and exclusively adopted for use in this country has now become an important and urgent practical question. The adoption of the metre system in its entirety, both for measures and weights, has been strongly advocated by a very influential committee, who are actively endeavouring to effect that purpose; and the object of the present paper is to compare the standards for measure of length, and to show the practicability of adopting a decimal system founded on the inch at present used in this country, and the advantages that the inch possesses over the metre as the standard unit of measure.

The first question of the desirability of a decimal system of measure may now be considered settled, and the principle definitely adopted in this country: but the second question of the standard of measure is still open, and is a very important one for consideration on account of the number of circumstances affecting it.

The adoption of the metre has been strongly recommended, and special efforts were made to get it fixed upon as the compulsory standard of measure for this country; but in the decimal bill now passed it is determined only to legalise the use of the metre in addition to the former standards in this country. The grounds on which the adoption of the metre has been urged are, the existence already of a complete decimal system of measure and of weights based on the metre, and its adoption already as the standard of measure by the large and important population of the French empire and several other countries: the object being to obtain if possible a universal standard of measure for the whole civilised world, on account of the great advantages that would attend the universal use of the same system of measures in the rapidly extending international communications.

The consideration of the standard of measure involves two distinct classes of requirements that have to be met as far as practicable, which need a separate examination, namely—those involving scientific questions for preliminary investigation; and those that are practical conditions necessary to be fulfilled before the object can be really carried out.

The scientific questions involved may be stated as follows:—

1. The standard to be the one that can be replaced best in case of being accidentally lost.

2. The standard to be the one most universal in the character of its basis of reference.

The practical conditions involved may be stated as follows:—

3. The standard to be the one best suited for use in decimal subdivision.

4. The standard to be the one most extensively and influentially in use already, and consequently involving the least alteration of existing measures.

1. In considering the question of the standard that can be *replaced best* in case of being totally lost by any accident, there appears on examination to be no real choice between the metre and the inch in this respect. The length of the metre was originally determined by measuring a portion of a quadrant of the earth's polar circumference; but its length was also referred to the length of a seconds pendulum, on account of the much greater facility for accurately repeating the measurement of a pendulum than the extremely difficult and complicated operation of measuring an arc of the earth's circumference. The length of the metre was consequently defined in 1798 by Borda, one of the commissioners for determining the French national standard, by giving 0·99385 metre as the length of a seconds pendulum at Paris making 86,400 oscillations in twenty-four hours, and vibrating in vacuo at the sea-level and at the temperature of freezing water.

The length of the inch was defined in 1824 by the declaration by Act of Parliament that 39·13929 inches is the length of a seconds pendulum in the latitude of London, vibrating in vacuo at the sea level and at the temperature of 62° Fahrenheit. Consequently both the metre and the inch can be verified by the same means, the measurement of a pendulum; and indeed the relation between them having been once established, it follows that whatever means is used for verifying the one, whether by the length of the pendulum or any measurement of the earth's surface, is equally available for verifying the other; so that in this respect there is not any choice between the metre and the inch.

2. In regard to the second point—the standard that is *most universal in the character of its basis* of reference—the metre was formerly supposed to have a marked superiority over the inch, as it was originally intended to be exactly the one 10-millionth part of a quadrant of the earth's polar circumference,* the basis of measurement to which it was referred; whilst on the other hand the inch was an uneven fraction of the length of the pendulum. The result however of subsequent and more accurate measurement has been to show an error of 1-640th part deficiency in the original measurement of the metre, which was effected in 1794 by the measurement of an arc of about 630 miles length, extending through France from the coast at Dunkirk to Formentera on the coast of Spain, the measurement of which was carried out under unusual difficulties in time of war. In consequence of this error in the original measurement for the standard, the length of the metre was now to be defined by an uneven fraction, as is the case in defining the length of the inch. The further result, however, of recent investigation has been to show, that a quadrant of the earth's polar circumference is not, as was previously supposed, a uniform quantity, and it is therefore not a suitable basis for determining a standard unit of measure; for it has been found that the form of the earth at the equator differs from a true circle, its longest equatorial diameter exceeding its

* Read at the Institution of Mechanical Engineers.

* Or more correctly the 1-100,000th part of a decimal degree of latitude of which 100 degrees made the quadrant, this degree being taken in France, and consequently differing in length from a similar degree in other latitudes on account of the polar diameter of the earth being 1-299th part less than its mean equatorial diameter, owing to its spheroidal form.

shortest by 1-3941th part, and there is consequently a variation in the lengths of different quadrants of the circumference measured from the pole to the equator. As regards the universality of its basis therefore, there is no choice between the metre and the inch.

It has to be noticed that the present legal standard of measure in this country, is really an individual standard metallic yard measure, which was legalised by Act of Parliament in 1855; this had been prepared with all possible care by comparison of all existing standards of authority, the former legal standard, a metallic yard measure made by Bird in 1760, having been destroyed by fire in the burning of the Houses of Parliament in 1834. In consequence however of some sources of error having been discovered by subsequent investigations in the former process of measuring the seconds pendulum, all reference is omitted in this last Act of 1855 to the means of verifying the standard by the length of the pendulum, and the only provision made against a loss of the standard is by legalising certain duplicates that were made from it with the greatest care, as secondary standards. The present standard of measure is therefore really an individual metallic yard measure, forming the legal standard independent of any reference to another source: and the metre may indeed be considered to be in a similar position, since it is a continuation or copy of the original metre, which is now known to differ from the measure of the earth's circumference that it was intended to represent, while the amount of error at present ascertained may probably undergo still further correction by future still more accurate observations.

The circumstance however of depending upon accuracy of copying for the preservation of a standard, though theoretically objectionable, is not practically a disadvantage as regards accuracy. For with the extreme degree of perfection now attained in copying measures of length by Mr. Whitworth's process of contact measurement, the accuracy of measurement can be carried as far as one millionth of an inch, which is a considerably higher approximation than can be obtained in any present process of determining the length of a pendulum or an arc of the earth's circumference. The writer is informed by Mr. Whitworth that the standard cylindrical gauges supplied by him to engineering and other establishments do not vary 1-10,000th inch in diameter for any size up to 2 inches, and the larger sizes up to 6 inches diameter do not vary 1-5000th inch.

In consequence of the variation in the lengths of the several quadrants of the earth's circumference, a suggestion has been made by Sir John Herschel to adopt the earth's polar axis as the standard of reference, that being the only single or unique dimension of the earth's mass. As this dimension is very nearly 500,500,000 inches or 1-1000th part more than 500 million inches, it has been proposed by him to increase the inch by 1-1000th part and make it then the standard unit of length as the one 500-millionth part of the earth's polar axis. It has to be observed however in reference to this proposal, that 1-1000th part of an inch is now an appreciable quantity in mechanical work, such as boring rifles, &c.; and the alteration if carried out would involve a loss of one mile in every 1000 miles. Moreover, independently of these practical objections, any such step would really involve a similar mistake to that made in originally fixing the metre, since the results of a future more correct measurement of the earth's axis would be likely to require a correction in the fraction expressing the inch, in addition to the present known error of 1-170,000th part, arising from the actual length of the axis being rather less than 500,500,000 inches, as ascertained by the present measurement.

All these various considerations therefore appear to lead to the conclusion that the best practical course is to refer to an individual standard, which will admit of being copied with a very high degree of accuracy, as in the case of the present legal standard in this country.

3. The next question, as to the standard *best suited for use in decimal subdivision*, is one to be determined by the relative practical convenience or inconvenience of the principal subdivisions and multiples of the different standards of length.

The old legal standard of measure in this country, the yard, is near the size of the metre, the former being 36 inches and the latter 39·3708 inches. If the yard were subdivided decimally into tenths, hundredths, and thousandths, it would make a scale as inconvenient and difficult of application in this country as the metre scale: but the standard is defined as a yard of 36 inches, and the inch as a unit of measure has important advantages as regards facility of application, and has a special qualification for the purpose as a convenient unit for expressing the smaller dimensions required in mechanical engineering work, since the subdivisions and multiples of the inch predominate in the dimensions of the parts of machinery, &c. For example, a measuring machine extending from 0 to 10 inches gives an ample range to make the requisite templates and gauges with an accuracy up to 1-1000th inch for all the boring and turning work required for locomotives and for stationary engines up to 100-horsepower, and for the tools and machines of corresponding size. The larger dimensions above 10 inches are but few in number as compared with those below 10 inches, and are not required to be more accurate than to 1-100th inch; their dimensions can therefore be obtained from a steel rule of 100 inches length divided into inches, tenths, and half tenths; while the half-tenth of an inch, being easily divisible by the eye into five parts, gives hundredths of an inch. The writer has found such a range up to 100 inches amply sufficient for the requirements of one of the largest locomotive establishments, and also for all the purposes of a large ironworks; and with such a system great accuracy of work is obtained, mistakes and misfits are avoided, and a duplicate system of the most perfect kind is established.

For small dimensions the metre is divided into 1000 parts called millimetres, each being equal to ·03937 inch or about 1-26th inch; but in the classes of work in which the finer dimensions of thousandths of an inch are required, the inch has an advantage over the metre in convenience of application as the unit of measure; for dimensions in thousandths of an inch are readily and conveniently expressed and spoken of, but with the metre as a unit such dimensions require the use of millimetres and fractions of millimetres carried to two places of decimals in order to express them. For example, the standard bore of the Government rifles, in which a difference of 1-1000th inch in the diameter of bore has to be recognised and expressed, is ·577 inch or 577 thousandths; but the expression of such a dimension on the metre system would be in the inconvenient form of 14·67 millimetres.

This is a practical advantage of importance in favour of the inch as the unit of measure; for dimensions to 1-1000th inch are now required in regular use for various descriptions of work. For example, in the case of fixing a wheel or a lever upon its axle, the amount of difference in diameter required between boring and turning, in order to ensure the correct amount of tension, is not a thing to be guessed at, but is a definite quantity ranging from 1-1000th to 5-1000ths inch, or ·001 to ·005 inch. If in addition to forcing by hydraulic pressure, as in the case of putting wheels upon their axles, the further step is taken of expanding the external portion by heat and then shrinking it upon its seating, as in fixing levers upon shafts, a very high degree of accuracy in the respective diameters is required in order to ensure a definite amount of tension; this is especially the case in the manufacture of wrought-iron ordnance, where one series of hoops has to be shrunk upon another, each layer being compressed in proportion to the work it is intended to sustain. These dimensions of thousandths of an inch are now readily appreciated and worked to in regular work by means of the system of contact gauges introduced by Mr. Whitworth; they can be measured by any good workman with a pair of callipers, and great advantage in accuracy and facility of work is derived from the system of working to these definite decimal dimensions.

It may also be observed that the inch divided into thousandths serves very conveniently to express the series of thicknesses known as the wire and metal gauges, as shown in Mr. Whitworth's decimal wire gauge, a specimen of which is on the table, extending from No. 300, or 300 thousandths of an inch, to No. 18 or 18 thousandths of an inch.

A decimal scale founded on the inch as the unit would have then for its subdivisions the 100ths and 1000ths of an inch at present in use; and the first ascending step in the scale would be the substitution of a 10-inch foot for the present 12-inch foot, being a reduction of one-sixth in the present measure. The succeeding measures would be as shown in the following table, taking merely for the sake of comparison a similar nomenclature to that of the metre scale:—

		Inches.	
Milli inch	=	·001	or thousandth of an inch.
Centi inch	=	·01	,, hundredth ,,
Deci inch	=	·1	,, tenth ,,
Inch	=	1	the Standard Unit.

	Inches.		
Deca inch =	10	⅚ foot of	12 inches.
Hecto inch =	100	about 1⅜ fathom ,,	72 ,,
Kilo inch =	1,000	,, 1¼ chain ,,	792 ,,
Myria inch =	10,000	,, 1¼ furlong ,,	7920 ,,
	100,000	,, 1½ mile ,,	63360 ,,

A corresponding decimal scale applied to superficial measure would be as follows:—

	Sq. ins.		Sq. ins.
Square inch =	1		
Square deca inch =	100	about ⅔ foot of	144
Square hecto inch =	10,000	,, ¼ pole ,,	39,204
Square kilo inch =	1,000,000	,, ⅙ acre ,,	6,272,640

In carrying out this change of the measures at present in use, it has to be observed that in consequence of taking for the unit the lowest of the present denominations—the inch—the important advantage is obtained that any dimension on the present system can be exactly expressed in the decimal system without any fractional remainder, and the only calculation required for the change is to bring the dimension into inches, which immediately gives its corresponding value in the decimal system. But if any other of the present measures, such as the foot or the yard, were taken as the unit, a troublesome calculation would be required for this purpose, just as in the case of adopting the metre for the unit; and the result would be an inconvenient fractional quantity, with its accuracy depending in many cases on the length to which the decimal was carried.

4. The last consideration is the standard that is the *most extensively and influentially in use* already, and consequently involves the least alteration of existing measures in its adoption.

The *metre* was established in France in 1840, and is now the measure in universal use throughout the French empire, and also in Belgium, Holland, and Northern Italy. It has also been subsequently adopted and has partly come into use in Spain, Portugal, Italy, and Greece; and also in Brazil, Peru, Chili, Mexico, and other countries in America. The population of the above countries is about as follows, taking the data from the *Almanach de Gotha:*—

			Population.
Metre in universal use	France, Belgium, Holland, and Northern Italy		50,000,000
Metre adopted and partly in use	European Countries	37,000,000	
	Ditto Colonies	35,000,000	
	American Countries	26,000,000	
			98,000,000
			148,000,000

The inch is in universal use throughout the British empire (excepting India) and throughout the North American States. In British India, the native standard measure, the "hath," is legalised as 18 inches; and a multiple of the inch is also the standard measure of the Russian empire, the imperial "sagene" being legalised as 7 feet English. The population of the above countries is about as follows, taken from the same source:—

			Population.
Inch in universal use	British empire (excepting India)	36,000,000	
	North American States	31,000,000	
			67,000,000
Multiple of inch in use	British India	138,000,000	
	Russian empire	74,000,000	
			212,000,000
			279,000,000

In addition to this excess in the actual numbers of the people now using the inch over those now using the metre, the fact should be considered that the former include the great machinery producers, whose work is already existing in such large quantities in all parts of the world in the form of engines, machinery, railway plant, tools, &c.; such as the tools and machines of Manchester and Leeds, so largely exported to other countries, their cotton and flax machinery, the sugar mills of the West Indies, the steam engines, agricultural engines, and machinery sent to all parts of the world, steamboats, railway plant and machinery, railway bridges and roofs, &c.; the amount of steam engines and machinery alone that has been exported from this country during the last twenty years having reached the value of £49,000,000, and averaging during the last five years about £4,000,000 annually. The large excess in the machinery already made under the inch over that made under the metre system of measure is an important practical consideration, as it must be remembered that the machines sent out to other countries form types of other machines, and that they require repairing and renewing with the same measures with which they were made. In this country the inch is involved intimately in all mechanical engineering work, and is the basis on which the various machines and engines have been built, as the mechanical engineer may be said to think in inches, calculate in inches, and work in inches; mechanical drawings are made to the inch or its multiples; patterns are in inches; the pitches of the teeth of wheels, the sizes of taps and dies, the standard gauges for boring and turning, and the finer dimensions of every part of every tool, machine, and engine, are all made in inches; and the sizes of all bars of iron and planks of timber are in inches. The inch is also the basis of the data for calculations of strength of materials, sectional areas of girders and framing, pressure of steam, &c., power, velocity, capacity, and weight. The difficulty of effecting any change in the unit now forming the basis of these measures and calculations would therefore be exceedingly great; but in the case of the metre this difficulty is greatly increased by the relation between the metre and the inch requiring a long fraction to represent it with sufficient accuracy for such purposes, thus:—

1 metre is equal to 39·3708 inches, and
1 inch is equal to 25·3995 millimetres.

In the following table are shown, for the purpose of comparison, the corresponding values in millimetres of some of the ordinary fractions of the inch, and the corresponding values of square and cubic inches in square centimetres and cubic millimetres; from which will be seen the extreme difficulty and inconvenience that would arise in attempting to change the inch to the metre system.

1 inch	=	25·3995	millimetres.
½ ,,	=	12·6998	,,
¼ ,,	=	6·3499	,,
⅛ ,,	=	3·1749	,,
1/16 ,,	=	1·5875	,,
1/32 ,,	=	0·7937	,,
1/64 ,,	=	0·3968	,,
1/100 ,,	=	0·2540	,,
1 square inch	=	6·451	square centimetres.
10 ,, ,,	=	64·512	,, ,,
1 cubic inch	=	16·386	cubic millimetres.
10 ,,	=	163·862	,, ,,

Considering the preponderance of the population now using the inch and not the metre, and the extent to which the inch is now spread over the whole world, the difficulties in the way of a change to the metre appear to the writer so insuperable, as to amount practically to a prohibition of a decimal system of measure if it is to be based on the metre.

The subject of decimalising the present very irregular and inconvenient system of weights and measures of capacity in this country is one of great importance; and great advantages would arise from the reduction to a uniform decimal system. It has been supposed that the metre system has an advantage in basing the system of weights directly upon the measures of length, the kilogramme of 2·2048 lb. English being intended to be exactly the weight of a cubic decimetre of pure water at its maximum density: but it now appears from subsequent more accurate measurement that this requires some correction, so that the relation between the kilogramme and the metre is not an even one as intended, but an uneven fractional one. There is strictly no choice therefore in that respect between the kilogramme and the pound; and in fact, in the same way as with the definition of the metre or the inch, any weight, such as the English pound, may be defined with equal accuracy for the standard unit.

It may be remarked that if the pound (pound avoirdupois =7000 grains troy) were taken as the standard unit for decimal weights, the important weights of the cwt. and the ton, which now vary in practice, the cwt. between 112 and 120 lb. and the ton between 20 and 21 cwt. or 2240 and 2520 lb., might be decimalised as 100 and 2000 lb. without any very serious difficulty, and with important advantage in removing another of the old irregularities in the system of weights and measures; just as in 1841 the imperial and decimal gallon, consisting of 10 lb. of distilled water at 62° Fahr. was substituted by Act of Parliament for the old ale and wine gallons having 102 and 83 per cent. respectively of the same value.

The following are the general conclusions submitted in the present paper in reference to the standard for decimal measure:—

1. That the inch and the metre are equally eligible for the purpose, as regards the basis of reference on which they are founded; and either of them could be as accurately and readily replaced as the other in case of being lost: since both of them are practically dependent upon the copying of an individual standard, which can be effected by the present improved means of measurement with a higher degree of accuracy than could be attained in a repetition of the original process of constructing the standard by reference to a natural standard such as a pendulum or an arc of the earth's circumference.

2. That the metre is not suitable for adoption in this country, on account of its entire difference from the existing measures and the inconvenience that would arise in expressing the smaller dimensions extensively used in mechanical work, &c.; and that the inch is the most suitable measure for the purpose, on account of its being intimately involved in the present data for calculations and dimensions of mechanical work, &c., and from its convenience for expressing the smaller dimensions extensively used. That for larger dimensions the easiest and most convenient decimal change would be the adoption of a 10-inch measure, which would be a reduction of an even fraction of $\frac{1}{6}$th from the present foot; and the longer measures being already multiples of the inch, the change would then be at least easier for their decimal adaptation to the inch than for their entire alteration to the metre standard.

3. That it is very desirable that an alteration should be made in the present system of weights and measures of capacity, for reducing them both to decimal systems; and that these can be based as definitely and conveniently upon the inch as the standard of measure as upon the metre; and that it will be preferable to adopt for the standard a weight that is already in most common use in this country, such as the pound, without attempting to construct any new standard bearing a more simple relation to the decimal standard of length, but differing from all the existing weights.

ON SOME OF THE CAUSES OF THE FAILURE OF DEEP-SEA CABLES, AND EXPERIMENTAL RESEARCHES ON THE PERMANENCY OF THEIR INSULATORS.*

By William Fairbairn, Esq., C.E., F.R.S.

The recent disaster and loss of the greater portion of the Atlantic cable is one of those casualties which may be considered national, and may be looked upon as a misfortune much to be regretted, as it delays the completion of one of the most arduous enterprizes that has taken place in marine telegraphy. It is, however, suggestive of improvements and the removal of impediments which seem to have beset the last attempt to submerge what was considered the best and most effective construction for a durable and certain communication between this country and America.

The lost cable, or that part of it which now rests as a lifeless thread at the bottom of the Atlantic, was unanimously selected by the scientific committee, to whom was entrusted a long series of laborious experiments to determine the strengths and other mechanical, chemical, and electrical properties of the material of which it was composed; and it may be interesting for the section to know how these experiments were conducted, and to what extent they were calculated to form a safe and a durable cable.

For these particular details I must refer to my own report, published in the Transactions of last year, in which will be found the mechanical properties of this and other cables submitted to various experimental tests. In this report the results deduced from these experiments are given, and we have now to inquire how far they were conducive to carry out the objects of the company in establishing a safe and effective communication between Valentia and Newfoundland.

It will be noticed that the late failure of the insulation, submergence, &c. is not an uncommon occurrence. On the contrary, it has been estimated that out of about 14,000 miles of cable that have been laid, nearly three fourths of that length have been failures, and that at the present time not more than from 4000 to 5000 miles are in successful operation. These repeated failures and loss of property are much to be deplored; but they have been, like the last great failure, fruitful as the means of accumulating a vast amount of experience, and have suggested remedies for the almost inevitable difficulties that have to be surmounted.

* Read before the British Association.

Conditions of Cables.—Considerable difference of opinion exists as to what constitutes the best description of deep-sea cable, some contending that a single copper conducting wire surrounded with a spiral covering of fine steel, such as Mr. Allan's indestructible deep-sea cable, and Mr. Siemens', who depends for the strength of his cable on a strand of copper wire laid round the central wire, and a series of white hemp strands as a protection to the insulating covering. Others again, such as Messrs. Glass, Elliot, and Co., maintain that the strength of the cable should depend on wires of homogenous iron, covered with strands of Manilla yarn saturated with a preservative mixture, and spirally wound round the padded core. This constitutes the strength of the Atlantic cable. There are other varieties, but they depend for their strength more or less upon an external covering of wire round the insulator. There are, however, two things in marine telegraphy which require special attention—viz., the manufacture of the cable, and its submergence in deep water. In the first we may venture to assume that the conducting wires, insulation, and strengths of the cables are satisfactory, and that we have nothing more to do than to lay it quietly on the bed of the ocean. The recent defects of the Atlantic cable and the imperfect insulation of others are, however, important lessons, which prove the necessity of vigilant inspection of every yard of cable as it is manufactured in the first instance, and its careful preservation until it is safely deposited at the bottom of the ocean in the second. All these conditions were supposed to have been carefully attended to in the manufacture of the Atlantic cable, when it was run from the machines into the water tanks at the manufactory, from these again into the steamer conveying it to Sheerness, and ultimately into those of the Great Eastern ship, where it was carefully coiled for final immersion. Every possible care was taken; but, notwithstanding the precautions exercised by the manufacturing company, small pieces of wire on three different occasions were found sticking in the cable in contact with the conducting wires, and destructive of the insulation. Now, these very trifling circumstances were the whole and sole cause of the loss of the cable, and it may be necessary as we proceed to advert to the subsequent trials of underlaying, dredging, fishing, and hauling, which ensued, and which finally terminated in the loss of nearly two thirds of the cable.

In my paper of last year I gave a full account of the experiments and results which led to the manufacture of the present cable, and I closed with the remark that "I had not entered upon the process of immersion either in tanks or the sea; and the question of coiling, shipping, submersion, &c., were left for future inquiry." I was in hopes that this inquiry would not have been necessary, excepting only to prove that the machines and every other appliance on board the Great Eastern had effectually performed their respective duties, and that we had only to record them as contributors to one of the most successful enterprises that had been achieved in modern times. In these, our most sanguine hopes, we have been disappointed, and we have now simply to inquire what extra precautions should be taken to prevent a similar occurrence in laying the next cable, which I hope to see done with perfect safety and without interruption at the bottom of the Atlantic.

Paying-out Machinery.—A voyage from the Nore to Valentia in July last, enabled me carefully to examine the big ship, with her machinery and valuable cargo. I inspected the tanks and machinery for paying out the cable in detail, and felt satisfied that every preparation had been made, and every precaution taken, to ensure success. The paying-out machinery was perfect; it proved itself to be so as regards its powers for regulating the quantity of slack to be paid out at different depths, and the uniform degree of tension that was requisite to be observed, and which I believe was given to it at these depths.

Coiling.— Paying out a cable of considerable weight and strength from the coil appears to be surrounded with many difficulties, the greatest of which is the danger of kinks, arising from the twist which it receives in being uncoiled. This is the great objection to every description of cable paid out from the coil, as the tendency is to run into loops or kinks, and this, when submitted to an amount of tension of not more than one-half its ultimate powers of resistance, would injure the insulation, and, what is more than probable, would ultimately destroy the conductivity of the cable. These are difficulties which in this weight of cable it is almost impossible to overcome. With a smaller cable, depending entirely upon the conducting wires—carefully insulated—for its strength, it would be possible to wind it in lengths of eighty to one hundred miles upon reels, and these, neatly balanced in the hold of the ship, might be paid out into the sea entirely free from kinks; but in doing this it must be observed that considerable risk is incurred of breaking the cable from the amount of friction to which the wheels would be subject when loaded with eighty miles of cable. Taking the whole conditions of these arrangements into account, it is not clear that the reels would be any improvement upon the large coils in tanks, as adopted in the Great Eastern ship. In fact, there is no other plan suitable for the paying out of the Atlantic cable, of its present weight and dimensions, but the coil.

Splicing.—As respects the manufacture and the splicing, it is evident that much greater care should be taken to see that no extraneous matter comes in contact with the insulator, or to injure the external covering after the cable is once finished. If the short pieces of wire which penetrated the gutta-percha had not been there the cable would have been at the present moment moment in full activity and in regular communication with the American States; and it is much to be regretted that this cable, so strong and so powerful in its resistance to strain, so well executed and so full of promise, should have failed.

The Great Eastern.—With regard to the Great Eastern ship, never was a company more fortunate in having such a vessel for such a purpose. She proved herself everything that could be wished for. Her easy steady motion was just what was required for paying out the cable, and its relief from any undue strain by the pitching of the vessel renders the big ship exclusively calculated for the submergence of submarine cables in deep water. She is the very thing that is wanted for such a purpose; and I firmly believe if she was properly fitted and prepared for such a service—with some additional stringers to strengthen the upper deck and sides—she would find full employment as a submerger of cables in every sea which divides the four quarters of the globe. She is admirably adapted for that purpose, and her double engines, with screw and paddles, assist the steering, and afford great facilities for paying out and hauling in the cable should accidents occur such as overtook the vessel in the middle of the Atlantic.

Recovery of the Broken Cable.—In speaking of the Great Eastern and her adaptation for laying the cable, it may be desirable further to inquiry into her capabilities for dredging, underlaying, and overhauling a cable if lost or broken in deep water. The recovery of a lost cable is at all times a precarious operation, and the difficulty which presents itself in the case of the Atlantic cable is its large diameter and the friction of its external surface in passing through the water. If raised at all it must be at an exceedingly slow speed, and that with one end loose, otherwise I should despair of raising it from a depth of 2100 fathoms, by hooking it in the bight or middle, where the resistance would be doubled in raising two sides instead of one.

Let us suppose that the grapnel has hooked the cable at a few miles distant from the fracture, and it will be seen—if it is to be raised from a depth of 2½ miles—that we have in the present cable to lift at an angle of, say 45 deg. on each side 3·18 miles of cable, or 6·25 × 14 cwt. (the weight of the cable in water), a weight of 4⅓ tons, equivalent to more than one-half the breaking strain. Now to this dead weight we have to add the friction of the two sides of the triangle, AB and AC, (Fig. 1, Plate 29*), which will be as the squares of the velocities with which it is raised. What may be the additional amount of strain from the speed with which it may be drawn through the water it is not necessary here to calculate, as it is obvious that at a velocity of two miles per hour it would approximate close upon the breaking weight of the cable.

Let us however assume, for the sake of calculation, the strain, including weight and friction, to be 6 tons, and as it requires a strain of 7¾ tons to break the cable, we only have in reserve 1¾ ton to carry the bight of the rope to the surface of the water. Now this is assuming that the cable has been paid out with as much slack as will enable it to be raised in the manner just described; but this is evidently not the case, and as any attempts at raising the cable in this form would break it, the slack of 1100 yards on each side would require to be taken up, and a drag for five miles on each side would be the result, before it could reach the surface. This is evident from the fact that the excess of cable paid out over the distance run was 1210: 1060, or 12½ per cent. of slack. This would be equivalent to dragging some miles of cable through the ooze or mud to make up the difference between the catenaries DE and AB, AC.

According to this reason it would appear that any attempt to raise the cable in this way would prove fruitless, unless some means were adopted to cut it at the point N on the American side, and haul in by a second grapnel which would hold fast until the cable was cut. These appear to be the remedies calculated to meet the difficulties by which the recovery of the cable at mid-Atlantic is surrounded, but I must confess that I have very great doubts of its success. The only feasible plan which suggests itself to my mind is to commence *de novo*, not to lay a new cable, but to place the Great Eastern under the cable at Valentia, and pick it up at a rate proportionate to the depth of water from which it has to be abstracted.

On the Construction of Submarine Cables.—I have to observe that their success depends on such a variety of circumstances—some of them exceedingly precarious—that the wonder is they have succeeded so well as they have done. Much, however, depends on the manufacture in the first instance, and the paying-out in the second.

In the manufacture of a submarine cable there is no difficulty with the conducting wire, if made of pure copper; but the greatest care and caution should be taken with the insulator, to see that the different coats of gutta-percha are pure, solid, and free from injury by the abrasion of the external covering when composed of strands of wire constituting the strength of the cable. To ascertain all these points a series of well-conducted experiments were made upon the material of insulation, and to ascertain the different degrees of permeability under great pressure. As some of the results may be interesting, I have tabulated them in the order in which they were made as follows.

The following experiments were prosecuted at the request of the commission, with a view to determine how far the different kinds of material proposed as insulating coverings for electric submarine cables were reliable when placed at the bottom of the ocean under the pressure of superincumbent pressure. It appears that all insulators which have been subjected to experiment absorb more or less water under pressure, even those that are closest in texture, such as vulcanised india-rubber and gutta-percha; and it appears that this absorption increases the longer the specimen is retained under water, the greater the pressure to which it is subjected, and the higher the temperature of the water in which it is immersed. The very limited time which has been available for these experiments has prevented my doing more than to indicate decisively these general facts, without determining the numerical relations of the quantities absorbed under different conditions of time, pressure, or temperature. But already the experiments point out a very important inquiry, some of the methods by which that inquiry may be prosecuted, and some of the conditions which must be attended to in order to insure reliable and corresponding results.

Generally in regard to insulating power the various materials tried arrange themselves in the following order of permeability, the first absorbing least water, and the last absorbing most:—1. Chatterton's compound; 2. Gutta-percha; 3. Masticated india-rubber; 4. Vulcanised india-rubber; 5. Carbonised india-rubber; 6. Wray's compound; 7. Unmasticated boule india-rubber.

The experiments on the insulating power of various cores under pressure are less complete than those on absorption, and have been prosecuted under greater difficulties and less variety of conditions.

So far as the experiments go, however, Wray's core exhibited very high insulating powers, retaining the charge longer than any other tried. Next in order to this may be placed a core of pure india-rubber coiled in two coats over a wire, but this very rapidly lost its insulating power under pressure. Then a core of pure gutta-percha cured by the Mackintosh process, and the experiments on this are perhaps the most satisfactory of the series; the pressure was retained upon the cable for 406 hours, in which period it exhibited considerable diminution of insulation. A core of twenty alternate coats of gutta-percha and Chatterton's compound also exhibited good insulation, unimpaired after 170 hours' immersion. The experiments on a core subjected to pressure in an insulating liquid before being placed in our hands give anomalous results. The insulation increased instead of diminishing as the liquid dissolved out.

The first experiments have for their object the determination of the increase of weight of various insulating materials when subjected to enormous pressure under water. A series of insulators were selected, such as gutta-percha, india-rubber, Wray's compound, Chatterton's compound, vulcanised india-rubber, india-rubber compounded with carbon, and marine glue. Of these, suitable sized pieces were prepared and placed in a strong steel cylinder, and subjected to pressure by means of a lever and plunger. Before their introduction into the cylinder, and while dry, they were carefully weighed in a delicate balance. Then, after being subjected to pressure for a shorter or longer period, as the case might be, they were again dried on the surface and immediately weighed. The increase of weight due to the pressure under water, is the measure of the quantity of water which had been absorbed, or rather forced into the pores of the insulator.

Fig. 2 represents the apparatus employed in these experiments. C is the large cylinder of wrought-iron in which the specimens were placed; P, its plunger, 2 inches in diameter. Fig 4 shows the general arrangement of the apparatus. L, L, the large lever; F, its fulcrum; and P, the plunger of the cylinder C, in which the weighted specimens were placed. The plunger is guided vertically by the box B, B, forming part of the general case or stand in which the lever is placed. By means of weights suspended on the extremity of the lever, the requisite pressure could be applied to the water in the cylinder C.

TABLE I.

First Series of Experiments on Absorption, under a pressure of 20,000 lb. per square inch, reduced to 100 hours' exposure and 10 inches area.—Reduced results.

No. of experiments.	Insulator.	Pressure in lbs. per square inch.	Equivalent column of water in miles.	Duration of exposure in hours.	Area of specimen in square inches.	Water absorbed in grains.
1	India-rubber	20,000	8·720	100	10	0·177
2	India-rubber with carbon	20,000	8·720	100	10	0·055
3	Wray's compound ...	20,000	8·720	100	10	0·072
4	Gutta-percha	20,000	8·720	100	10	0·044

The temperature in all these experiments was low, sometimes several degrees below freezing point. In the first experiment, with Wray's compound, the cylinder when opened was found to be filled with loose ice.

Here the last column shows the gutta-percha to be the least absorbent, and the india-rubber most so. Wray's compound absorbed more than carbonised india-rubber, but less than pure india-rubber. The pure india-rubber seems to combine superficially with water, as the surface becomes white, either at parts, as in the present experiment, or over the whole surface. The carbon appears to prevent the formation of this hydrate, and at the same time reduces the elasticity of the native rubber, and enables it to be worked more kindly.

In the next series the whole of the specimens were placed in the same cylinder, and remained under pressure during the same period and under the same conditions. (See Table II.)

These tables show that, of all the substances tried, native unmasticated india-rubber absorbs by far the most water. The whole surface of the specimen had lost its black colour, and become whitened during the experiment. Taking the mean of three experiments, very closely agreeing, we find that native india-rubber after manufacture absorbs less water than in its native state, in the proportion 0·682 to 3·075, or 1: 4½. Vulcanised india-rubber appears to be the least absorbent substance tried, but when combined with carbon it absorbs nearly one third more water (according to the results in this table) than in its pure masticated state. Gutta-percha and Chatterton's compound are nearly alike in their resistance to absorption, the latter being superior. In these experiments they increased in weight only one-half as much as pure india-rubber (masticated), and twice as much as vulcanised india-rubber. Wray's compound absorbed rather more than masticated india-rubber. Marine glue lost instead of increasing its weight.

Comparing these experiments with the last, we find that these materials are far from following a law of simple proportion in the amount of water absorbed in different times. The present experiments were made under a pressure of 5900 lb. per square inch, and lasted for a period of 450 hours. The last were made under a pressure of 20,000 lb., and lasted less than 100 hours. In the present experiments carbonised india-rubber absorbed seventeen times as much as in the former; Wray's compound, ten times; gutta-percha, seven times; and masticated india-rubber only four times. Hence it appears that, other things being equal, masticated india-rubber would be most advantageous, and carbonised india-rubber least so, as insulators; because, so far as these experiments afford data for generalising, masticated india-rubber follows a rate of absorption diminishing most with time, and carbonised india-rubber least so. This deduction, however, is complicated by the fact of a difference of pressure, and possibly of temperature, in the two experiments.

TABLE II.

Experiments on Absorption, under a pressure of 6000 lb. and at the ordinary temperature.—Results reduced to 10 inches area.

No. of experiment.	Insulator.	Pressure in pounds per square inch.	Equivalent column of water in miles.	Duration of exposure in hours.	Area of specimen in square inches.	Water absorbed in grains.	
1	India-rubber unmasticated	5,900	2·575	450	10	3·075	
4	India-rubber masticated	5,900	2·575	450	10	0·023	
8	Ditto ditto	5,900	2·575	450	10	0·636	0·682
9	Ditto ditto	5,900	2·575	450	10	0·700	
10	Ditto ditto	5,900	2·575	450	10	0·711	
11	India-rubber vulcanised	5,900	2·575	450	10	0·146	
7	India-rubber carbonised	5,900	2·575	450	10	0·980	
2	Gutta-percha	5,900	2·575	450	10	0·378	0·307
13	Ditto	5,900	2·575	450	10	0·177	
14	Ditto	5,900	2·575	450	10	0·366	
5	Wray's compound ...	5,900	2·575	450	10	0·750	0·725
13	Ditto	5,900	2·575	450	10	0·700	
6	Chatterton's compound	5,900	2·575	450	10	0·375	0·279
12	Ditto	5,900	2·575	450	10	0·183	

The order of merit in resisting absorption, as derived from this series of experiments, is:—1. Vulcanised india-rubber; 2. Chatterton's compound; 3. Gutta-percha; 4. Masticated india-rubber; 5. Wray's compound; 6. Carbonised india-rubber; 7. India-rubber, not masticated.

The next series of experiments was made under greater pressure, but in the same manner and for the same period of immersion:—

TABLE III.

Third Series of Experiments on Absorption at ordinary temperatures.—Reduction of results to 10 inches area.

No. of experiment.	Insulator.	Pressure in pounds per square inch.	Equivalent column of water in miles.	Duration of exposure in hours.	Area of specimens in square inches.	Water absorbed in grains.	
6	Raw India-rubber ..	15,000	6·54	450	10	1·65	
7	Masticated india-rubber	15,000	6·54	450	10	0·22	0·26
8	Ditto ditto	15,000	6·54	450	10	0·29	
9	Ditto ditto	15,000	6. 54	450	10	0·30	
10	Carbonised india-rubber	15,000	6·54	450	10	0·29	
5	Gutta-percha	15,000	6·54	450	10	0·18	
1	Wray's compound ...	15,000	6·54	450	10	0·56	0·57
2	Ditto ditto	15,000	6·54	450	10	0·58	
3	Chatterton's compound...	15.000	6·54	450	10	0·054	0·057
4	Ditto ditto	15,000	6·54	450	10	0·058	

The temperature during these experiments was generally lower than in the second series, being frequently at the freezing point. There was loose ice in the cylinder when opened.

The higher pressures in these experiments seem to bring out more decisively the differences in the amount of absorption; but it is remarkable that while the relative absorption does not widely differ, and the order of the insulators in their resistance to absorption is the same, the absolute quantity absorbed under greater pressure is less than in the previous series of experiments. The only discrepancy between the two series of experiments is the relatively low absorption of masticated india-rubber.

The order of merit or power of resisting absorption is, in these experiments:—1. Chatterton's compound; 2. Gutta-percha; 3. Masticated india-rubber; 4. Carbonised india-rubber; 5. Wray's compound; 6. Raw india-rubber.

The last in this series absorbed twenty-seven times as much as the first; gutta-percha and Chatterton's compound hold, as before, the highest place, but the superiority of the latter was more manifest—it had become whitened at the surface, but apparently the water had penetrated the thinnest possible film.

The next experiments were made with a view to determine the effect of temperature on the absorption of water by these insulators. Recourse was had to the small cylinder *c*, Fig. 4, which was surrounded by the water bath *b*, *b*, maintained at a uniform temperature of 100 Fahr. by the gas jet *g*; *t*, *t*, is the thermometer. The lever by which the pressure was applied to the plunger is shown at L, L, attached to the firm cast-iron base A, A.

The different substances were tried separately, as in the first series, and the weighings were repeated at intervals. During the night it was necessary to remove the gas jet, as the uniformity of temperature could not be depended upon; hence, for half the period of immersion the specimens were at a temperature of 50° only, and for the remainder at the temperature of 100.° The loss of weight after removal from the cylinder, in consequence of the evaporation of the water absorbed, was in these experiments noted, and it was found the specimens decreased in weight below their original weight when dry.

In the whole of these experiments the pressure was 20,000 lb. per square inch; area of specimens 8 square inches, and thickness about ⅛-inch.

TABLE IV.

Fourth Series of Experiments on Absorption at increased temperature.—Results reduced to 100 *hours and* 10 *inches area.*

No. of experiment.	Insulator.	Pressure per square inch in pounds.	Duration of exposure in hours.	Temperature Fahr. (mean.)	Area of specimens in square inches.	Water absorbed in grains.	Loss of weight in drying.
3	Gutta-percha ...	20,000	100	75 deg.	10	0·27	3·61
4	India-rubber ...	20,000	100	75 „	10	0·45	0·87
5	Wray's compound...	20,000	100	75 „	10	0·58	0·91
6	Chatterton's compound	20,000	100	75 „	10	0·20	0·60
7	Vulcanised rubber...	20,000	100	75 „	10	0·80	2·27

Comparing the numbers in this table with those in the first series, which were made under precisely similar conditions in all respects, except temperature, which then did not exceed an average of 40° or 45° Fahr., it becomes evident that temperature has a considerable effect on the amount of water absorbed. Thus, gutta-percha at 45° absorbed 0·044 grains, at 75°, 0·27 grains, or six times as much. In like manner, india-rubber absorbed 0·177 grains at the lower temperature, and 0·45 at the higher, or 2½ times as much. Wray's compound 0·072 at the lower temperature, and 0·58 at the higher, or seven times as much.

Reasoning upon the foregoing experiments, a question arises, as to the ratio or quantity of water absorbed in different times, and the condition of the specimens after a much more lengthened immersion. The present expe iments, although showing the relative permeability of different insulators, do not afford data to determine the ultimate condition of the material intended to surround and insulate the conducting wires of the electric cable. To ascertain these facts a much more enlarged series of experiments is required, extending over a much greater length of time. If for example, gutta-percha absorbs ·015 grains of water in 100 hours, under a pressure of 20,000 lb. on the square inch, we want to determine the corresponding quantity absorbed in 1000 hours; and further, at what period will the continuous absorption cease? These are questions of vital importance as regards the porosity of the specimens; and when ascertained we should still require to know to what extent the insulation of the electric current would be impaired in the cable saturated with moisture.

Should our best insulaters, such as Chatterton's compound or gutta-percha, as given in the experiments, arrive at a point at which they will absorb no more water under a given pressure, it then becomes necessary that we should ascertain whether the water imbibed is sufficient to carry off the whole or part of the voltaic current, and whether the passage of the current through the insulator would accelerate, in turn, the oxidation and consequent destruction of the conductor. To solve these questions we require, in my opinion, a long series of carefully conducted experiments, which would tend to give a reliability to these important undertakings which at present they have not attained.

ON CHAIN TESTING MACHINES.*

By SIR W. G. ARMSTRONG.

THE engineering firm of which I am a member having been entrusted with the construction of the apparatus for testing chain cables and anchors, lately established at Birkenhead by the Mersey Harbour Trustees, had occasion to enter into a very careful consideration of the conditions requisite for effecting the operation in the best possible manner. As public attention has been forcibly directed of late to the importance of more accurate methods of testing chains and anchors, a few observations on the subject of the Birkenhead machine will not at the present moment be mistimed.

The most important consideration in the construction of a chain testing machine is to obtain an accurate indication of the strain upon the chain. The hydraulic press has been for many years the appliance universally employed for exerting the strain, and nothing can be better fitted for the purpose; but the methods of determining the amount of the strain have been extremely imperfect. Most commonly the strain has been estimated by the indications of a mitred valve pressed down by a lever and weight. The impossibility however of restricting the tightening surface of the valve to a definite annular line, so as to exclude any variation of area, rendered this mode of indication highly delusive; so much so indeed, that the attendants generally paid more regard to the indication afforded by the crackling of the scale on the surface of the iron than to the amount of load upon the valve. By substituting a loaded plunger for a loaded valve, the uncertainty arising from variability of surface is obviated, but a plunger requires a packing to make it watertight, and the effect of the friction of this packing has to be considered in relation to the friction of the press. A plunger without friction would give untrue indications of the strain unless the press were also without friction; but friction cannot be avoided in the press, and therefore friction becomes a necessary element of accuracy in an indicating plunger. To make this more apparent, it is only necessary to consider that in the press the friction of the packing lessens the tension exerted on the chain; while in the case of the indicator the friction of the packing lessens the weight necessary to indicate the pressure. If therefore these two frictions be in harmony, the load on the indicator will be diminished in the same proportion as the tension on the chain, and thus a correct indication of the strain upon the chain will be obtained.

The proper and usual packing for the hydraulic press is a cupped leather; but as the lip of the leather is pressed against the surface of the ram by the action of the water, the amount of its friction varies directly as the pressure. It is therefore necessary that the indicating plunger should also be packed with a cupped leather, in order that its friction may likewise vary directly as the pressure. But as the ratio of circumference to area is very much greater in the small ram of the indicator than in the large ram of the press, it is obvious that with similar leathers the relative friction would be widely different in the two cases. The friction may however be brought to a proper adjustment by reducing the breadth of the lip in the leather of the indicator until its friction is in unison with that of the press leather. This adjustment should be made when the press ram and the indicator plunger are both perfectly clean and free from any lubricating substance, and in no subsequent use of the machine should either oil or grease be applied to these parts. The effect of employing a lubricator is to diminish the friction in the first instance, but afterwards to increase it, because the unctuous character of the lubricant is soon exchanged for a stickiness, which produces an opposite effect. In fact, when grease or oil are used, the frictions become so irregular as to render impossible an accurate correspondence between the press and the indicator.

There is another desideratum in the testing of chains, which

* British Association, 1865.

requires a further elaboration of the indicating apparatus. When a chain breaks in the test, it is desirable to show, not only that it failed to bear the full test strain, but also what was the amount of strain exerted at the moment of fracture. In the case of the Birkenhead machine, various indicators upon the principle of those commonly used for steam pressure were tried, for the purpose of effecting this latter object, but none of them gave satisfactory results. An apparatus was therefore designed for this object, which has since come into very general use, under the name of the Pendulum Indicator. In this apparatus the pressure upon the indicating plunger is exhibited by the travel of a pendulum through a graduated arc. The movement is communicated from the plunger to the pendulum, through the medium of a compound lever. When a chain breaks, the pendulum falls back until stopped by a ratchet, but leaves a marker at the exact point on the scale attained by the pendulum at the moment of rupture.

I have hitherto spoken of friction only in reference to the packing of the apparatus. This friction, as I have already stated, varies with the pressure, but there is also the constant friction due to the weight of the moving parts to consider. If the machine be used exclusively for high strains in relation to its weight this constant friction will be unimportant; but if a heavy machine be used for testing light chains, a considerable element of error will be introduced, unless a proportionate friction of the same constant character be added to the indicator. Still, however, it is better that very heavy machines should not be used for testing light chains, unless they be constructed with more than one press to act separately for light chains, and conjointly for heavy chains. With this view the Birkenhead machine has three presses, the centre one being used alone for light strains, and the three acting in concert when great strains are to be exerted.

Although an hydraulic indicator, properly constructed and correctly adjusted in regard to its friction may be safely relied upon as indicating with sufficient precision the strain exerted by the machine, yet for the purpose of ascertaining in the first instance when correct adjustment has been attained, and also of detecting any discrepancy which may subsequently arise from dirt upon the ram or plunger, or from any other cause producing irregular friction, it is necessary that every machine should be provided with a lever indicator, to which the chain may be directly applied, and the strain ascertained by the lifting of a weight. Such an apparatus requires to be accurately fitted with knife-edge bearings in order to afford delicate indications, but, as these are liable to deterioration by too frequent use, it is better to reserve the lever apparatus as a standard of reference for adjusting the hydraulic indicator, which is not liable to deterioration by use. It is not necessary that the lever indicator should range as high as the hydraulic indicator, for if the two indicators register alike through a sufficient series of the lower strains, no discrepancy would be manifested if the comparison were carried to the highest powers of the machine.

I may here mention that nothing so soon deteriorates the lever apparatus as inadequate length of the knife-edges in relation to the strain upon them. The conclusion arrived at in the Elswick Works is, that not less than one inch length of edge should be allowed to every five tons of strain upon the bearing.

In the arrangement of a public chain testing establishment it is desirable that the apparatus for the various operations should be placed in such succession as will allow the chains to move from process to process without any retrogression. The Birkenhead chain testing establishment commences with a store-room for the reception of unproved chains. From the store each chain is dragged by a steam power capstan through an opening in the partition-wall on to the testing-bench of the machine. It is there made fast at the one end to the press, and at the other to a cross-head supported on live rollers, which cross-head may either abut against a stop or be connected with the lever indicator. After the chain has been proved it is dragged by a second capstan directly forward in the same line into the examining room, and there stretched upon one of the benches, where it undergoes a close inspection. If found perfect it is then hauled forward by a third capstan through the heating oven and blacking trough, and is thence passed complete into the delivery store at the opposite end of the establishment. The course of the chain being thus in one straight line, it is necessary to carry it over the machinery at each end of the testing-bench, and to accomplish this a channel of wrought-iron is fixed over the machinery to support the chain in its passage. Should the chain fail in the test, or be found defective on examination, it is drawn off by one of the capstans to smiths' fires placed on the floor of the examining room, and, after repair, is again hauled to the testing-bench for a second proof. For the convenience of handling heavy chains at the smiths' fires an hydraulic crane is connected with each fire. Between the testing and examining rooms there is an intermediate room called the indicator room, in which the lever and hydraulic indicators are placed, and the valves of the apparatus manipulated by an attendant in view of the indicators. Anchors are received into the same store-room as the chains, and the usual appliances are provided for fixing them in the test. Over-head cranes are employed for lifting the anchors as well as for lifting the chains in the two stores. There are two testing machines in the establishment, fixed at opposite sides of the room. These are similarly arranged in every respect, but one of them is adapted to test up to a strain of 200 tons, and the other to 300 tons. The hydraulic pressure is supplied from a neighbouring accumulator used for a system of hydraulic machinery at work in the adjacent dock.

As the general practice is to make chain cable in lengths of fifteen fathoms, the Birkenhead machines are adapted for that length. The Board of Trade have recently fixed upon that length as the limit of length of chain to be tested at one time. The propriety of their so doing has been called in question, but I may state that it is the opinion of those persons who have the management of the Birkenhead machines, that no advantage of any kind would be gained by testing chain in greater lengths. If there is to be a limit it is clear that such limit is best fixed at the length at which chains are usually made.

There is besides a positive objection to exceeding that limit, because a greater length than fifteen fathoms cannot be tested without the use of intermediate supports, which, whether they be slides or rollers, are objectionable, as being liable to produce variations of strain in different parts of the chain. Another objection to permitting indefinite lengths of chain to be tested at one time arises out of the stretch to which chains are subject in testing. This stretch occasionally amounts to five feet in fifteen fathoms, and if that length of chain were greatly exceeded it would involve a press of very inconvenient length, or necessitate taking repeated holds of the chain, which would be highly objectionable. I think, therefore, that the Board of Trade have acted wisely in imposing a limit, and in fixing that limit at fifteen fathoms.

ON THE OUTER COVERING OF DEEP-SEA CABLES.*

By C. W. Siemens, C.E., F.R.S.

The want of success which has hitherto attended deep sea cables renders it, perhaps, desirable that the attention of this section should be called to the subject. We are able, at present, to point to shallow sea lines, such as the Dover and Calais, Port Patrick, Donaghadee, and the Dover and Ostend lines, which have lasted above fourteen years, and in which the electric conductors together with their insulating coating remain to this day unimpaired, although the thick iron wires which constitute their outer covering are greatly diminished in strength through oxidation, and have given rise to occasional repairs.

It has, moreover, been proved beyond doubt, that the great hydrostatic pressure upon deep-sea cables does not deteriorate the insulated conductor, but, on the contrary, greatly improves the insulation; and, as regards the durability of the outer covering, deep-sea cables have the natural advantage over shallow sea lines that they lie upon tranquil ground, far beyond the reach of currents, of accidental disturbances through ships' anchors or the coral fisher's hooks, and, to some extent at least, beyond the reach of animal life.

The drawbacks to these advantages are, that the risk of accident is greater in laying down deep-sea lines, and that when laid they are less accessible for repairs; but these circumstances do not suffice to account for the very rapid failure of those deep-sea cables which had been successfully submerged; as, for instance, the first Atlantic, the Toulon and Algiers, and other lines in the Mediterranean.

But why, it may be asked, are deep-sea cables not precisely the same as shallow sea or shore-end lines, seeing that the latter have given proof of greater strength and durability? The

* Read before the British Association.

answer is that the laying of a heavy iron-clad cable into deep seas would be attended with great risk, because the retarding force which has to be applied to a cable in going overboard increases with the depth (or length of suspended cable), and would amount to several tons; tug steamers would have to be applied to assist the cable ship, and any stoppage in the operation through the breakage or entanglement of a wire or other cause, might seriously compromise the safety of the cable and of the ships themselves. Moreover, deep-sea cables are generally long cables, and ships could hardly be found to carry a heavy cable of the requisite length in one piece, nor could it be joined with safety on the open seas. The risk of breakage of a heavy deep-sea cable would also be great, because the thick iron wires composing the same could hardly reach down to the bottom of the North Atlantic without breaking by their own dead weight.

Considering these circumstances, it becomes evident that the strength and permanency of a deep-sea cable cannot be attained by thick iron wires, but that other materials and modes of construction must be had recourse to.

In reviewing past experience we find that in the case of the Varna and Balaklava cable (300 miles), which was laid in 1858, no sheathing of any kind was applied to the insulated conductor. The operation of paying out was accomplished with great ease and success by Messrs. Newall, and the electrical communication was kept open for nearly nine months, when it suddenly ceased, in consequence either of chafing against rocks or shells, or the tooth of the teredo.

Several cables were laid in the Mediterranean in 1855 and 1856, consisting of an insulated conductor covered with strings of tarred hemp, which was laid on in the manner of an iron sheathing. A difficulty was experienced in laying this description of cable, owing to its excessive specific lightness and roughness of surface, which combined to make it sink so very slowly to the bottom, that it was paid out, as it were, in a straight line upon the surface of the water, and although no brake power whatever was applied, not sufficient cable would leave the ship to cover the irregularities of the bottom.

This tightening of the cable, when laid, was further increased by the shrinkage of the hemp strings in the water, and moreover by the action of local currents in the water, to which the cable remained exposed for a long time during its descent. The consequence was, that the cable strained and broke during the operation of laying, or rather immediately after. In raising this cable a few months later it was found, moreover, that the hemp had engendered millions of small marine insects of a peculiar kind (the Xelophega according to Huxley), who had not only completely destroyed the rope, but had eaten deep holes into the gutta-percha, without reaching, however, the copper conductor. This action had been accomplished at a depth of from 300 to 600 fathoms.

Several heavy iron-covered cables have been laid into moderately deep water in the Mediterranean, some of which were laid successfully, though at great risk, and with great loss of cable, and have worked for several years before giving way. The most remarkable is the Spezzia and Corsica cable, which consisted of six insulated conductors, served with tarred hemp, and sheathed with twelve galvanised iron wires of three-tenths of an inch diameter, producing a weight of 8½ tons per mile of cable. This cable was laid in 1854, in a depth of 600 fathoms, and remained in good working order till 1863, when it failed.

The Red Sea and Indian cable was laid successfully in 1859-60, but failed after nine months' exposure to the sea-water, when it was found that the iron sheathing, consisting of sixteen wires, and weighing 2 tons per mile, had been completely corroded through in places.

The first Atlantic cable, which was laid in 1857, had a sheathing of a peculiar form, consisting of 126 thin charcoal iron wires of No. 22½ B.W.G., giving it great relative strength during the process of laying. Considering, however, the large exposure of iron surface to corrosive action of the sea, this cable must have failed a few weeks after submersion if the insulated conductor had not been so defective in itself as to render the cable unfit for regular telegraphic communication from the first.

Another type of sheathing for a deep-sea cable is that which was adapted for the Toulon and Algiers line in 1860; it consisted of ten steel wires of No. 10 B.W.G., each of which had been previously covered with tarred hemp, for the purpose of giving it additional strength and protection against corrosion. It was proved by experiments that the strength of each steel wire was increased to the full amount of the strength of the hemp serving, or about 20 per cent., while at the same time the specific gravity of the cable was greatly decreased, and its descent through the water further retarded in consequence of the rough surface the hemp serving presents.

The insulated conductor of this cable was well proportioned and carefully tested, and its sheathing was found to be such that a moderate brake power sufficed to prevent its running out too fast in the laying, while at the same time the cable descended with sufficient rapidity to provide the necessary slack (about 12 per cent.)

Thus far the compound sheathing of steel and hemp had proved a complete success, when about six months after its submersion the continuity suddenly ceased, and in endeavouring to raise the cable it was found that the marine insect, Xelophega, had again done the work of destruction, having completely eaten the hemp in many places, and left the steel wires like a loose cage around the insulated conductor, fully exposed to corrosive action.

These repeated failures of the outer covering of deep-sea cables led the writer to devise one which combines the requisites of low specific gravity and relative strength with greater durability than could theretofore be attained. A cable of this description actually forms an important link in the telegraphic chain which now unites France with its African dependency, and is, therefore, practically entitled to consideration.

It consists of the ordinary insulated copper conductor, which is covered in one process with two layers of best Italian hemp moderately twisted in opposite directions, and lastly, with an outer binding sheathing of copper, which is put on under great pressure, and in such a manner that the copper strips composing the same overlap, and are, as it were, morticed into one another, producing practically the effect of a complete flexible tube. Each string of hemp is put on in the machine under an equal strain, which gives to the rope a strength fully equal to the sum of all its constituents. The metal of the outer sheathing is copper, mixed with about one-fourth per cent. of phosphorus, which imparts to it greater tenacity and an increased power to resist chemical action in the sea-water. Instead of copper, zinc has sometimes been used, which also resists sea-water in a remarkable degree.

The hemp gives great relative strength to this cable. The Algeria cable with an outer diameter of only half an inch, bears a strain exceeding 1½ ton; and a cable of the dimensions proposed by the writer for the Atlantic, having a diameter of three-quarters of an inch, bears between 3 tons and 4 tons of longitudinal strain before breaking, or fully as much as an iron-covered cable of the same diameter, while its weight in sea-water is from five to six times less.

The machine used in the manufacture of this cable presents several novel mechanical combinations, which the writer will, however, pass over, in order not to widen the subject of this paper. The peculiar properties of this cable, as contrasted with the ordinary cable, with helical or spiral sheathing, are as follow:

1. The absolute strength of this cable can be increased to any desired extent without adding to its weight in water, the hemp being very nearly of the same specific gravity as the water itself. Considering past experience, a specific gravity of 1½, and a strength sufficient to support from ten to twelve miles of weight of the cable in sea-water, appears desirable.

2. The elongation of this cable under half its breaking strain does not exceed one-half per cent., and has no tendency to untwist when suspended from one end; whereas an iron sheathing cable (or a cable of the Toulon and Algiers type) will elongate from 3 per cent. to 4 per cent. under similar circumstances, and partially untwist at the same time, because each wire tends to assume a straight line parallel to the axis. This elongation throws a great and dangerous strain upon the insulated conductor, which will be permanently elongated and disposed to fall into kinks at the bottom.

3. In the manufacture of iron-clad cables the insulated conductor frequently gets injured through the breakage of a wire or the carelessness of workmen in making welds, and the cable, when manufactured and in the very act of being paid overboard, may be penetrated by the sharp end of a broken wire, as has most unfortunately happened on a recent occasion. The copper sheathed cable precludes almost the possibility of any such accidental injury; the insulated conductor, after being carefully tested, passes through the sheathing machine, where it receives

spontaneously its double hemp covering and complete metallic armour coating. It is worthy of remark that the insulation resistance of the core invariably increases in receiving the armour coat, owing, it appears, to the external pressure produced, and that not a single fault of insulation has ever occurred in the cable during the processes of shipment and submersion.

4. The durability of the copper-sheathed cable has already been proved by experiment and in actual practice. A cable which had been laid in 1864 in the Mediterranean, from Oran to Carthagena, was partly raised again nine months later, in consequence of an accident of a purely mechanical nature, from a depth of 1500 fathoms, when it was found to be in a perfectly good condition, the insulation and the strength of the hemp being unimpaired, and the copper sheathing being covered by a thin green scale of chloride of copper and magnesia, it is supposed, which appears to have arrested further chemical action. The cable so recovered, and of which a specimen is exhibited, now forms part of the line connecting Sicily with Algeria; whereas the iron-sheathed shore end, which was also recovered, was found to be unfit for further use, being much corroded and covered with coral growth.

5. The copper-sheathed cable is mechanically well suited to the operations of laying, it is extremely flexible, occupies relatively little space in the ship's hold, and glides smoothly overboard, without the least risk of catching by broken wires, or of forming into kinks, or untwisting under strain. It offers remarkably little resistance in the water, and can be recovered from the greatest depth at the rate of one knot per hour.

It has been objected that hemp rope contracts very considerably (about 3 per cent.) upon being immersed, and that the copper sheathed cable must be liable to the same injurious effect. While fully admitting the general proposition, the writer has no difficulty to show that it does not apply to the cable in question.

It will be seen from the experiment which will be shown to the meeting, that although a twisted hemp rope contracts upon being moistened, a single hemp fibre taken from the same rope actually elongates under the same treatment, the reason being, as it appears to the writer, that each hemp fibre consists of a series of collapsed tubes between knots, which, upon filling with water, straighten from knot to knot, and therefore slightly augment the total length; whereas the same fibre, if wound spirally, will reduce the length of the spiral in consequence of its increase in diameter in filling with water. Proceeding from this consideration, hempyarn of little twist is used in the manufacture of this cable, the copper sheathing binding the fibres sufficiently to continue their strength, and the result is that its length remains practically the same upon being immersed.

In drawing this paper to a conclusion, the writer feels that he has laid himself open to the charge of partiality in favour of one particular covering, but his excuse is that he could not have done otherwise without doing violence to his convictions, which however are open to criticism. So much will, he thinks, be readily conceded, that the failure of deep-sea cables has hitherto been mainly due to the mechanical imperfections and perishable nature of the outer coverings. The unfortunate attempt to establish telegraphic communication with America goes to strengthen this proposition. Both the insulated conductor and the paying-out machinery had been prepared with extreme care; the great ship was well adapted to its important work, which in all human probability would have been crowned by success, but for the unfortunate injuries which the insulated core received through insufficient protection. The recurrence of the same kind of accident may perhaps be avoided by special care; but there remains the dangers of kinks at the bottom, through the untwisting of the rope while in suspension, and, most of all, the question of durability, to be disposed of.

It has been maintained by some that the outer covering of deep-sea cables is only of use for submerging the same, and that its decay at the tranquil bottom of the ocean could not harm the insulation; but such a proposition is disposed of by experience; and it is indeed natural to suppose that the sheathing must give way in such places where it rests upon a stone or gentle elevation of the ground, and is most exposed to chemical action. Upon giving way the cable will sink, to take new bearings, and cause the unsupported insulated conductor to separate. It may, on the contrary, be maintained that a permanent metallic sheathing is requisite to ensure the success of deep-sea as much as of shallow-sea cables.

THE WROUGHT-IRON ROAD BRIDGES OF THE CHARING-CROSS RAILWAY.

(*Concluded from p. 279.*)

Mr. Frederic C. Reynolds, referring to Fig. 7, Plate 20, said he believed it represented a bow and string bridge, but before he proceeded further he would be glad to be informed whether it were a bow and string bridge in the true sense of the term. By a bow and string bridge he understood a bridge formed of girders, in which the top member was composed of a column capable of supporting compression, and of such shape that it should contain within it, or nearly so, the curve of equilibrium due to the weight upon it. This top member should in fact constitute an arch; differing from an ordinary arch in the fact that instead of the horizontal strains being taken by the abutments they should be resisted by a tie rod or bottom member. He (Mr. Reynolds) had no doubt the bridge in question was a well-designed bridge of its kind, and capable of supporting any load that might be put upon it under ordinary circumstances, but nevertheless he believed he could show that a bow and string girder was not of as economical a form for a bridge as a girder properly so called—*i.e.* a warren or a lattice girder. In the case of a bridge under the most favourable circumstances, the bow should have a curve corresponding to the curve of equilibrium due to the weight carried by the bridge (explained by diagrams). In a bridge with a bow and string girder of the simplest form, the top member must be equal in section throughout, or rather increased towards the ends, and would have the same section in the centre as a warren lattice or plate girder would have in the top and bottom member, but there was this important difference, that in the case of the warren lattice or plate girder, the top and bottom member would, unlike the bow and string, be diminished towards the ends, so that the top member of an ordinary girder would contain only two-thirds as much iron as the top member of a bow and string girder; and the tie, under similar circumstances, would be composed of only two-thirds the amount of iron as would be in a bow and string, and the diagonals of, say a warren girder, would not do more than make up the top member equal to that of a bow and string. Under the very best circumstances, therefore, the bow and string girder must be heavier than an ordinary girder even without the diagonals, which must be provided for passing loads. It would appear, consequently, that a bow and string girder considered in the abstract could hardly be considered an economical, and therefore advisable form, unless there be some special reason for its adoption.

With respect to the joint pin of a warren girder, he had often found that the surface of the pin was inadequate to sustain the pressure brought upon it, or that would be brought upon it before the pin would be sheared or the bar pulled through. Suppose, for instance, a bar of a certain section which was wide and very thin, and a hole were made in this bar to take a pin of such a size that the sectional area would only be equal to the section of the bar, then it would be evident that the surface of the pin pressed upon by the bar, even allowing the half circumference to be effective, would be nothing like equal to the section of the pin. Thus, a bar 7 in. $\times 1 = 7$ sq. in. area, with a 3 in. pin, which would be 7 sq. in. section, would give only $4\frac{1}{2} \times 1 = 4\frac{1}{2}$ sq. in. surface pressed upon.

Mr. Latham said that the application of wrought-iron to bridge building was of quite a modern date; but at the present time its use was being carried to too great an extent. He thought that as every structure was subject to strains of compression and tension, and as cast-iron was better suited to resist compressive strains than wrought-iron, and wrought-iron better suited to resist tensile strains than cast-iron, that an economic structure should comprise a combination of both wrought and castiron. With regard to the questions that had been raised as to the best mode of securing the cross girders to the main girders, he preferred rather to place them on the bottom flange of the girder, than suspend them from it. He also considered that every part of a bridge should be accessible for examination and repair; and any bridge which did not offer facilities for examination was defective. The roadway of every bridge should be made impervious; otherwise, there was a leakage of water into the work, which, in addition to being a great nuisance to those who make use of the thoroughfares under such bridges, was prejudicial to the structure of the bridge itself; and the point bridge constructors should consider is the best mode of getting off with rapidity any water falling on the bridge.

The abutments of girder bridges at the present day are often neglected, and the result is, that it is nothing uncommon to see them giving way, which may, in most cases, be attributed to the structure not being able to withstand the pressure of the ballast, which is brought into active operation owing to the presence of water at the back of the abutment. The injurious action of this water may be got rid of by the simple expedient of introducing drains, constructed with a view to carry it away and prevent its hurtful accumulation.

Mr. H. P. Stephenson agreed with Mr. Reynolds as to the economy of lattice or plate girders over bow and string girders. In a bow and string girder the whole compressive strain is transmitted through the arch to the abutments, the string receiving the tension, the duty of the inclined lines being merely to transmit the weight to the arch; if the bracing were sufficiently strong to transmit the strain to the horizontal line, then the girder was no longer a bow and string girder, but became a trussed arched girder, and he believed the bridge in question should be considered one of that description, and not a bow and string girder.

Mr. Lefeuvre stated that, in his opinion, the bridge over the Thames was of an admirable design, although there were defects in some parts of it. The bridge was divided into 154 ft. spans, but owing to its having to carry four lines of rails instead of two lines, the bridge might be considered as divided into 308 ft. spans. He thought the diameter of the cylinders small, considering the immense weight they had to bear. He thought the cylinders should have been carried deeper into the clay. The diameter of the cylinders in the bridge varied, and he should like to know whether any calculation was made when the different diameters were arrived at. He thought it a very ingenious construction, seeing that land cost so much on the north side of the bridge.

Mr. Pendred said, that the largest bow and string bridge carrying a railway, with which he was acquainted, was that over the Shannon at Athlone. It had two spans; the upper member was a box, which took the whole of the strain. Mr. Carrington had said nearly all that he had to state with reference to drilling and punching of plates. After all, it was a mere question of cost; he did not think there was anything like 10 per cent. in the difference between the results obtained. Punching machines were not what they should be, for, after being used a little while, the punches became blunt, when there was a drift action which seriously affected the strength of the iron. He thought punches should work at a high speed. From an article which appeared in the *Engineer* (Oct. 14th), it would seem that the strength was in favour of the punched plates. It was much to be regretted that there were no well-authenticated experiments, in order to determine this question. In the best rivet joints there was at least one rivet in every hundred practically of no use, and in an inferior class of work there would be more than 10 per cent. of bad rivets. It did not appear that drilling could secure the correctness of the holes, so long as a drift was employed to bring the plates together subsequently.

Mr. Perry F. Nursey observed, that among the points advanced by the author of the paper, as being worthy of discussion, was that of the permanent way on the bridges of the Charing-cross Railway. As the question had not been touched upon by any one present he would offer a few remarks thereon, and place before the meeting some particulars of the permanent way which had been adopted on the bridges of that line.

There could be no question that the permanent way of such bridges as they were dealing with, or in fact any railway bridges, was a matter which had to be carefully considered before it could be decided on. There were many elements at work which militated against the adoption of any ordinary arrangement. The character of the permanent way, doubtless, had a great influence on bridges, and involved much care in determining on the system to be adopted. The main points were, a sound and well-bedded sleeperage, good and even rails, of a section neither too heavy nor too light, a perfect arrangement of breaking joint in all parts, and an uniform adaptability of the way, as a whole, to the character of the structure carrying it; or, in other words, to have the relative elasticity or rigidity of each so balanced that, as a whole, they—the permanent way and the bridge—should have a coincident action under traffic.

The system adopted on the Charing-cross bridges appeared to embody these points. The rail used was of the flat bottom or contractor's section, weighing 75 lb. per yard run, 5 in. deep, and about 4¾ in. wide in the foot. The rails were placed on longitudinal timber sleepers, 14 in. wide ×7 in. deep, to which they were fixed by wrought-iron angle-chairs or brackets, 2 ft. 6 in. apart, centre to centre, placed in pairs. The brackets were 6 in. wide, and about ½ in. thick in section, and the rails were secured in them by 1 in. screwed bolts, which passed through the well of the rail. The brackets were fixed to the longitudinal sleepers by ¾-in. spikes. The gauge was 4 ft. 8½ in., and was preserved by transoms, 6in.×6 in., which were placed in the 4 ft. 8½ in. way about every 6 ft., and in the 6 ft. way at intervals of from 12 to 20 ft. These transoms were connected to the longitudinals by means of 1 in. bolts passing through the latter, and of sufficient length to hold them well together. This made a very good permanent way, well suited to the purposes for which it was designed.

The only objection he would take to it was the use of the brackets in pairs. He thought the purpose would be answered equally well if they were placed *singly*, on the inside of the rail, the outer edge of the foot being held down by a dog bolt. And for the reason following—viz., that, as the thrust of the traffic on the rail resolved itself into a force tending to overturn the rail—the outer edge acting as a fulcrum—so no good purpose was served by the outer bracket, the rail there needing only to be kept from sliding; but on the inside it was necessary to secure the rail by a bracket and fang bolt, or similar fastening, in order to resist the strain put upon it under traffic, which strain was tending to draw the bolt from the sleeper; the amount of leverage obtained being that due to the distance between the fang bolt and outer edge of the rail. Hence the outer bracket became a superfluity.

The ordinary permanent way of the Charing-cross Railway consisted of a double-headed rail, fished, and weighing 75 lb. per yard, laid at a cant of 1 in 20. The fish-plates were 15 in long, and 1 in. thick, bolted with four 1 in. bolts. Cast-iron chairs were used, weighing from 28 to 30 lb.; the width at seat of rail was 5 in., base of chair 13 in.×5¾ in. Each chair was bolted to the sleeper with two ¾-in. bolts, with square heads and fang nuts. Oak wedges 8 in. long were used. The sleepers were 9 ft.×10 in.×5 in., placed about 2 ft. 2 in. centre to centre at joints, and about 2 ft. 10 in. at intermediate portions.

Mr. J. Lacey remarked that at the last meeting some allusion was made to the pins which held the struts being defective, which had not since been explained, and he had heard it remarked also that the calculations were not so carefully made as they ought to have been. If it was so it might result in a serious weakness in the bridges.

Mr. A. Williams did not approve of the practice of suspending the cross girders to the bottom flanges of the main girders either with bolts or rivets. He considered that if they could not be fixed in their proper theoretical places on the top flange, they should rest on the bottom flanges of the main girders, and be bolted to the web of the main girders; they would thus tend to prevent any lateral twisting of the main girders, and, in his opinion, convey more directly the weight suddenly coming upon them to the main girders, than if the cross girders were suspended to the bottom flanges, for in this case, any weight coming upon them must fall first on the rivet heads that connect them to the bearing girders; and from practice it is well known that nothing is easier than to render the head of a rivet useless, by the workman either not hitting the rivet fairly on the top, as it should be, to swell the rivet out so as to completely fill the hole, or by using burnt rivets; in the first case, perhaps, only half of the head of the rivet is over the hole, and, in the second, not sufficient iron to make a proper head to the rivet. These are errors that can be avoided by proper supervision, but where a large number of men are employed it would be impossible to see every rivet knocked down. He did not consider that drilling was practically more advantageous than punching the holes of plates to be riveted together to ensure good work, for the first thing a workman did to bring the holes opposite to each other was to insert a pointed steel drift, and drive it in, to bring the holes of all the plates in a proper position, thus with drifting spoiling the drilled holes.

Mr. Parkes, in reply, said he did not know what calculations were made. In the Thames bridge there was a deficiency of sectional area, and in the bow string bridge there was an excess of sectional area. The load was 750 tons. If the distance between the centres of gravity of the upper and lower chord were taken at 12 ft. 9 in., it gave a central strain of 1·132 tons. For the bridge over the Thames, the strains in the upper and lower chord, at any vertical section, were equal for any load.

He was of opinion that iron was injured by being punched, and when a large number of similar plates was required drilling was the cheapest and best. The reason the distance between the centres of the cross girders was reduced in some cases to 3 ft. was to gain headway, by having the cross girders shallower, which would have required very heavy flanges if the 4 ft. distance had been preserved. As regarded the making of the bridges of wider spans, so as to provide for the widening of streets, that was purely speculative, for railways might obviate the necessity for widening streets. He would observe that the difference in length of the largest bridges in winter and summer was such as to make rollers necessary. In either a bow string, a warren, or a plate girder, the "bending moment" and the "shearing force" of the load had to be resisted. In the first case, the diagonals had to meet the excess of the shearing force due to a partial load above that due to an uniform load. In the two other cases the diagonals or webs had to sustain the entire shearing force due to a partial load. It seemed to be the general opinion that it was not advisable to combine cast and wrought-iron in compound structures. It was difficult to keep bridges water-tight when the whole platform vibrated under the action of a passing load. He thought it would be better to arch the cross girders, and introduce small longitudinal girders between them, one line of them to be under each line of rails; this would divide the platform into a system of rectangular spaces, each to be covered with a plate. The longitudinal rail timbers to be packed on blocks spaced about 12 in. As regards the difference of strain, Mr. Reynolds stated that there might be a difference between the strain at top and bottom, which he (Mr. Parkes) did not agree with. The cross girders were attached entirely by rivets, excepting in the approach and Southwark-street bridges; in the first only bolts, in the second both bolts and rivets. He thought that in such a bridge as that over the Thames, the centre of the pins ought to coincide with the centres of gravity of the upper and lower chords respectively. Referring to the policy of keeping iron bridges well painted, he observed, that at one cleaning of the Menai Bridge no less than forty tons of iron rust were removed.

The Chairman said that, as a rule, the ordinary web and flange girder was preferable to a box girder, or a girder with cellular flanges, on account of the difficulty in cleaning and painting the interior of box girders, but he believed that man-holes were left in the girders of this description which were used on the Charing-cross Railway. Still, he did not see that there was an absolute necessity on this railway for making any girders that could not be easily inspected as to the state of the iron work and painting. The Charing-cross bridge over the river was so constructed that every part could be cleaned, painted, and readily inspected, so as to be assured that such maintenance was properly done.

As regarded the greatly ventilated question of attaching cross girders to main girders, he considered the method adopted in the large bridge over the river was a perfect one, as all the rivets were subjected to a shearing strain, which ought to be the principal duty of rivets in bridge building, if the rivets were subjected to a great strain, and not, as was often the case, fulfilling the duty of bolts. He made it a rule, when applying bolts which were subject to a great tensile strain, to have them made with a nut and screw at each end, so as not to run the risk of bad welds in forming the heads of the bolts; he therefore was of opinion that the method of attaching the top flanges of cross girders to the bottom flanges of main girders, by means of rivets, was one of the most unsatisfactory plans that could be adopted, and that the method of attaching the cross girders to the main girders by means of long bolts continued to the bottom flange of the cross girders, was a much more satisfactory solution of the question, as the advantage of elasticity in the length of the bolts, as compared with short rivets or short bolts, would have a material effect in preventing the heads of the rivets or bolts from being broken off. He objected, as a rule, to connecting cross girders underneath main girders, and was of opinion that cross girders should be so connected to main girders as to form something analogous to the ribs of a ship, and so as to have the effect of stiffening and keeping straight the upper flanges of the main girders, which were often required to be of a less width than could be safely applied without being so stiffened, and he presumed that the box girder principle had been adopted to some extent on this railway in consequence of not obtaining much assistance from the cross girders for laterally stiffening the top flanges of the main girders.

There was a great difficulty in making the platforms of railway bridges water-tight, so as to prevent water dripping through after rain had ceased. The methods adopted on the bridges in question made the platforms practically water-tight until the line was opened, when signs of leakage appeared. Various methods had been tried on other railways to make water-tight platforms, but, so far as he was aware, they had all failed, apparently from the vibration caused by the engines and trains. There were bridges in and near London with corrugated iron fixed underneath the bridges for carrying away the water that leaked through the platform, and he was of opinion that the best plan was to assume that the platform would leak, and that it would be a useless expenditure to endeavour to stop leaks, and therefore to at once, when designing a bridge over a much-used road, to arrange for corrugated iron or zinc, with necessary gutters and down pipes, to be fixed underneath the bridge, so that the leakage should cease to be an annoyance. During the discussion it had been mentioned that the effective area of metal as required by the strains per square inch was less in the centre of the bottom flanges of the Charing-cross Bridge girders than in the top flanges at the centre. He was of opinion that the strain on the bottom flange of those girders was less than in the top flange, and that the areas were properly proportioned. It was also mentioned as a defect in these girders that the pins for connecting the diagonal bracing to the flanges were not in the centre of the mass of metal in the flanges, but he was of opinion it was of very little consequence, as the effect of such position of the pins was to put a small transverse strain in the flanges, caused by the tendency in the mass of metal of the flanges to get in the position of the line of strain, which was the centre line of the pin holes.

As regarded the question of punching or drilling holes in iron for bridge building, there was no doubt that drilling was the most satisfactory plan, as the engineer was practically certain as to the strength of the plates, &c., when the holes were drilled, but in the case of punching holes he was not at all certain of the result, as various qualities of iron would be more or less weakened, in addition to the metal actually punched out. Hard iron would be more injuriously affected by punching than soft iron.

[The foregoing practical paper on the Wrought-iron Road Bridges of the Charing Cross Railway, was written by Mr. Matthew Parkes, C.E., and read before the Society of Engineers, the annual volume of Transactions of which excellent society, for the year 1864, has recently been published by Messrs. E. & F. N. Spon, London.]

PATENT LAWS AND COPYRIGHT.

The patent laws necessarily absorbed considerable attention at the Birmingham meeting of the British Association, as among the members present there were many who have during the last few years taken a prominent part in the controversy which the subject has occasioned. A paper on the patent laws was read by Prof. Rogers, of which the following is a condensation, and which, together with the notes of the discussion thereon, has been furnished to us by Mr. Spence, of Quality-court, Chancery-lane, who was present on the occasion:—

The professor began by adverting to the antagonism of feeling on the subject, in the following terms: "It cannot be said that there is any unanimity felt about the privileges or rights implied in the possession of these monopolies, for if the defence of the existing practice has been maintained with increasing warmth, the attack on the whole system has been and is being carried on with no diminution of vigour." And he added words to the effect that the opponents of such privileges or rights would not be deterred from discussing the question by the hard words applied to them by the defenders of the existing system, especial allusion being made to Mr. Mill's expression of "free stealing," as characteristic of abolition of legal protection.

The professor next referred to "The right of property," in which he spoke of the limitations on individual use and exercise required by the interests of society. "Many men (said he) receive more from social order than they render to it: those whose social position is the highest, most of all, and therefore are more justly the objects of such limitations as are conceived or proved to be safeguards to the interests of society itself. In order, however, that this right of property should be held sacred, even under the limitations put upon it, it is necessary that the possessor should prove his title, that there should be no possible confusion between his personal right and the right of another, and that his right should not be repugnant to general interests." Then it was alleged that the principle of property in patents failed when tried by these tests.

The question of "benefit to inventors" was next dwelt upon. On this point the professor said: "Every one is anxious that the labourer should have all possible opportunity for gaining what the public judges to be the worth of his labour, but it is alleged that the present system is, instead of being an aid, a real hindrance to so desirable a result." The position of an inventor was described as that of a gambler, and one who was exposed to the consequences of hard terms with capitalists, who were said to be opposed to the restrictions of patents.

"The position of the public" formed the third division of the paper, which topic was thus introduced: "It is assumed by the defenders of the patent system that the public is fairly compensated by the bargain tacitly made in the grant of a limited protection to inventors. On the one side is awarded a right of sole sale; on the other is secured the ultimate reversion of the invention, if indeed the patent be not continued on the plea that the patentee has not reaped as much as he thinks himself entitled to, or his patent be not virtually extended by the addition and incorporation of some new particulars." Under this head it was contended that patents hindered the progress of practical science and improvements in manufactures; and the protection afforded to an inventor was against other producers, at the cost of the consumer.

The fourth point urged in the paper related to "the fulness with which protection is accorded to all inventors alike." Under this division of the subject it was assumed, for the sake of argument, that the patent laws were consonant with public policy, both in principle and detail, but denied that they dealt out equal justice to all alike. The professor said: "It does not even under these favourable circumstances (those supposed) follow that they (the patent laws) are just, equitable, or expedient, since the protection is accorded almost entirely to mechanical invention, and ignores other branches of labour, intelligence, and discovery. The administration of law and justice exists for all alike." And this assertion is illustrated by a reference to a few examples in order to show that there is no legal protection afforded to discoveries of great public benefit in other departments of inquiry besides those connected with manufactures. Reference was made for this purpose to the discovery of coprolites, of gold in Australia, and of vaccination.

Then the last point referred to was the law of copyright. On this point the following assertions were made: "It is manifest that literature is not in fact protected by law to the extent that mechanics are. It is very doubtful whether it needs protection at all, or whether copyright has more than a putative protection. The most costly of literary labours—news gathered for the daily press—are freely copied from the most valuable; that is, from great works of profound scientific research or real public interest, extracts are made abundantly in newspapers and reviews. It may be doubted that a single copy more is sold by reason of copyright. It may be doubted whether a single copy less would be sold if the reprint by other hands were permitted." And the only protection asserted to be necessary was that which would result from making "the assumption of an author's name or a publisher's trade mark the object of a criminal prosecution."

An animated discussion followed the reading of the paper, the principal points of which are given in the subjoined report:—

Mr. Bramwell contended for a patent law, on the ground that it was requisite to afford some protection to a man to induce him to be at the trouble and expense of getting an invention adopted. He spoke of the natural difficulties in the way of its adoption, as inventions of importance often proceeded from men who were not in the trade, whose minds were not trammelled by being as it were in a groove of the particular shape produced by connection with the trade. It was natural that those in the trade who had set up a plant of machinery, should be averse to anything that would supersede it. And yet it was to the interest of the public that the changes referred to should be introduced, which result could not be attained by any other means so unobjectionably as by a patent law. The inventors could not be rewarded by honours, or by entering upon the trades to which their inventions related. Mr. Bramwell admitted that the existing patent law was defective as to its administration, but contended that it could be made to answer its required purpose, by such an administration of it as would insist on a proper intelligible specification, for if an alleged invention did not admit of being properly specified, it was not fit to be patented. He also referred with approval, to Mr. A. V. Newton's suggestion as to patentees being required to make out a *primâ facie* case before being admitted to trial. He contended that improvements of this kind, and a limited inquiry into novelty, would remove many objections.

Mr. Vignoles criticised Mr. Bramwell's arguments, but without producing any effect on the minds of his hearers.

Mr. Newmarch defended patents in a speech of remarkable fluency and clearness, which produced an evidently favourable effect on the meeting. He objected to a paper on purely abstract points, such as those treated by Prof. Rogers, as inconsistent with the kind of inquiry appropriate to the section of economic science and statistics. He considered that as to property it was an accepted principle, that the man who had spent capital and labour in any pursuit, had thereby made a property in it, which ought to be recognised. He considered therefore, that the creations of the brain, whether in the shape of a book or a mechanical invention, ought to be alike protected. And it was unfair to talk of abolishing patents, without attempting to make the existing system effective by developing its capabilities, so as to afford facilities to inventors and others interested in patents for searching into the novelty of inventions, and also to provide an efficient tribunal for trying questions of right between patentees and the public.

Lord Houghton also spoke in favour of patents, regarding them as a means of gaining for the use of the public inventions which would otherwise be lost sight of without producing the permanent results of which they were susceptible.

Mr. J. S. Wright, Vice-President of the Chamber of Commerce, spoke as a Birmingham manufacturer, in favour of patents, on the ground of the benefit they had conferred on manufacturing districts generally, and Birmingham in particular. He repudiated the notion of the likelihood of men going on inventing, if they had no legal recognition as inventors. He mentioned instances of men not taking out patents, leaving their secrets undivulged at the time of their deaths. He also spoke of the fettering effects of necessary secresy in trade, if there were no patent law. Mr. Siemens said, that, owing to the protection of inventions by the English patent law, he had been induced to leave his native country, and settle in England. Other persons spoke in favour of a patent law, and no one spoke against it. Lord Stanley made no comment on the discussion, but called on Prof. Rogers to reply, which he did shortly.

ON THE MANUFACTURE OF CAST-STEEL, ITS PROGRESS, AND EMPLOYMENT AS A SUBSTITUTE FOR WROUGHT-IRON.*

By Henry Bessemer.

On the 13th of August, 1856, the author had the honour of reading a paper before the Mechanical Section of the British Association at Cheltenham. This paper, entitled "The Manufacture of Malleable Iron and Steel without Fuel," was the first account that appeared shadowing forth the important manufacture now generally known as the Bessemer process.

* Read before the British Association.

It was only through the earnest solicitation of Mr. George Rennie, the then president of the Mechanical Section of this Association, that the invention was, at that early stage of its development, thus prominently brought forward; and when the author reflects on the amount of labour and the expenditure of time and money that were found to be still necessary before any commercial results from the working of the process were obtained, he has no doubt whatever but that, if the paper at Cheltenham had not then been read, the important system of manufacture to which it gave rise would to this hour have been wholly unknown.

In the original fixed converting vessel, as patented and erected in London for experimental purposes in 1856, the tuyeres were passed through the sides of the vessel in a horizontal direction, the result was that the blast of air entered only a short distance into the fluid mass, and much of it escaped upwards between the sides of the vessel and the metal. The effect of this was the rapid destruction of the brick lining, caused by the excessive temperature generated in the process, and the solvent property of the resulting silicate of protoxide of iron, which sometimes destroyed a lining of half a brick in thickness during the blowing of two charges of metal for about twenty minutes each. Another difficulty arose from the impossibility of stopping the process without running out the metal, for if the blowing ceased for one instant the fluid metal would run into the tuyeres, and stop them up.

A great inconvenience of the fixed vessel also arose from the danger and difficulty in tapping out the fluid malleable iron with a bar, after the manner of tapping an ordinary cupola furnace, for the blast had to be continued during the whole time the charge was running out of the vessel, in order to prevent the remaining portions from entering the tuyeres. A similar difficulty arose while running in the crude metal from the melting furnace, since it was necessary to turn on the blast before any metal was run into the vessel, the first portions so run in were, in consequence, partially decarbonised before the whole of the crude metal had left the melting furnace.

These were among the more prominent difficulties that had to be remedied. It is, however, satisfactory to know that even in this, its infant state, the process and apparatus were practically successful, in proof of which there is placed upon the table part of a malleable iron railway bar made from pig iron, at Baxter House, by blowing air through it in the apparatus just described, the fluid malleable iron having been run into a 10 in. square ingot mould, and the bloom so made rolled direct into the bar shown. The small malleable iron forged gun will serve as an example of the clearness and freedom from cracks or flaws in malleable iron so made and forged under the steam hammer. It is one of the very early productions of the process, and, like the malleable iron rail, was made wholly without any re-carbonising of the metal or the employment of spiegeleisen or manganese in any form whatever. Malleable iron so made from hematite pig iron is red-short, like all other wrought-iron made wholly from hematite; but that it is perfectly malleable and extremely tough when cold may be seen on examination of the iron rope exhibited, which consists of four rods of 1¼ in. round iron twisted cold into a close coil. These bars extended 13 in. in length in 4 ft., and were reduced nearly ⅛ in. in diameter in the operation of twisting, thus showing that malleable iron so made possesses an extraordinary degree of ductility.

It may be remembered that an important part of the process, as described at Cheltenham in 1856, consisted in tapping the fluid crude iron from the blast furnace, and allowing it to flow direct into the converting vessel, and be there blown to the extent only of decarbonising it so far as to produce cast steel. This part of the original programme has been most successfully carried out in Sweden, where an extensive establishment for its manufacture has been erected by M. Göranson, of Geffle. The large steel circular saw plate exhibited is an example of the conversion of crude cast-iron run direct from the blast furnace into the converting vessel, and there blown for nine minutes, in which period it had been converted into cast steel of the desired quality, and was then poured into an ingot mould without being re-carbonised, and wholly without the employment of spiegeleisen or manganese in any form whatever.

With these few illustrations of the capabilities of the process as originally described at Cheltenham, the author will proceed to show how the disadvantages of the old fixed converting vessel were remedied and other improvements introduced. Many forms of converting vessels were tried on the large scale before this desirable object was attained. In some of them the lining was too easily broken down by the violent motion of so heavy a fluid as iron; in some of the forms tried the angles allowed the metal to solidify in them, and so clog up the vessel; in others, the mouth of the vessel being too small, caused the metal to be thrown out by the force of the escaping blast. It was also found that if the mouth was too large the heat escaped, so as to cause part of the converted metal to solidify in the vessel; the relative height and diameter of the vessel was also found to produce important differences in the working of the process; finally, and after many long and expensive trials, the form of vessel shown at B and C was adopted.* This vessel is made in two parts, so as to admit easily of its being lined up with a pulverised silicious stone, known as "ganister," which so resists the action of the heat and slags as to last for fully 100 consecutive charges of steel before it is worn out. Its form is that of the arch in every position, which prevents the lining from falling down by its own weight. There are no angles in which the splashes of metal can solidify and accumulate. Its mouth directs the flame and sparks away from the workman, and from the moulds and other apparatus; while the throat of the vessel, and the position of the mouth, almost entirely prevents the throwing out of the metal. The vessel is mounted on trunions supported on stout pedestals, so that a semi-rotary motion may be communicated to it at pleasure. The tuyeres are placed at the bottom of the vessel, so as to force the air vertically upward through the metal, as shown, without coming in contact with the sides of the vessel. When the crude metal is to be run into the vessel it is turned on its axis nearly into the position shown at C, the mouth being a little higher up; a gutter will then conduct the crude cast-iron from the melting furnace into it. It is not necessary to turn on the blast until the whole of the metal is run in, because the tuyeres occupy a position above the level of it. As soon as the air is admitted through the tuyere the vessel is turned into the position shown at B, when its decarbonisation immediately commences. As soon as this is effected as much molten pig iron made from spathose iron ore is added to it as will restore the quantity of carbon necessary to produce the desired quality of steel, which is then run into the casting ladle in the manner shown, and from whence it is transferred to a series of iron moulds ranged in a semi-circular pit, each mould being placed within the sweep of the casting crane; the filling of these moulds is regulated by a cone valve made of fire-clay, and fitted in the bottom of the casting ladle, so as to be opened or shut at pleasure by means of a handle on the outside of the ladle.

It will be readily understood that in the fixed vessel first described any giving way of a fire-clay tuyere would stop the process, and cause much inconvenience; but with the movable vessel it is not so, for at any moment of time during the process the vessel may be turned on its axis and the tuyeres raised above the level of the metal; the blast may then be turned off, the tuyere box opened, and the faulty tuyere stopped up or removed, after which the process may be again resumed. The movement of the vessel on its axis, the rise and fall of the casting crane, and the other cranes employed for removing ingots from the casting pit, are all effected by a simple hydraulic apparatus, so that the whole process is under the perfect control of a single operator, placed far away from the heat and showers of splashes that accompany the process.

Up to this period the manufacture of cast steel by the old as well as the new process is still so far imperfect that steel of the highest quality cannot be made from inferior iron. In the old Sheffield process the original quality of the Swedish charcoal iron employed governs the quality of the cast steel made; consequently, £36 per ton is freely given for the high class Dauamora iron, while other brands of Swedish charcoal iron may be bought for £15. In either case these are expensive raw materials for the cast steel maker.

In 1839 the trade of Sheffield received an enormous impulse from the invention of Josiah Marshall Heath, who patented in this country the employment of metallic manganese, or, as he called it, carburet of manganese. The addition of a small quantity of this metal, say from one-half to one per cent. rendered the inferior coke-made irons of this country available for making cast steel; it removed from these inferior qualities of iron their red-shortness, and conferred on the cast steel so made the property of welding and working soundly under the hammer. This invention was of immense importance to the town of Sheffield, where its value was at once appreciated. Mr. Heath, supposing himself secure in his patent, told his licensees, that if they put oxide of manganese and coal tar or other carbonaceous matter into their crucibles along with the blister steel, that it would do as well, and be much cheaper than the carburet of manganese he was selling them; in effect it was the same thing, for before the steel was melted the carbon present reduced the oxide of manganese to the metallic state, so that his patent carburet of manganese was formed in the crucible in readiness to unite with the steel as soon as it became perfectly fused. But the law decided that this was not Heath's patent, and so the good people of Sheffield, after many years of litigation, were allowed to use it without remuneration to the inventor.

Manganese has now been used for many years in every cast steel works in Europe. It matters not how cast steel is made, since manganese added to it necessarily produces the same beneficial changes; no one better appreciated this fact than the unfortunate Mr. Heath, as evidenced by his patent of 1839, in which he declares that his invention consists in "the use of carburet of manganese in any process whereby iron is converted into cast steel." Had Heath seen in his own day the Bessemer process in operation, he could not have said more; he well knew the effect produced by manganese on steel, and, therefore, claimed its employment in any process whereby iron is converted into cast steel.

With this patent of Heath's expired, and become public property, coupled with the universal addition of manganese and carbon to cast steel, it would naturally be supposed that the author, in common with the rest of mankind, would have been allowed to share the benefits which Heath's invention had conferred on the whole community, but it was not so.

The reading of the author's paper at Cheltenham in 1856 was by the powerful agency of the press communicated in a few days to the whole country. Great expectations of the value of the new process were formed, both by scientific and practical men, in proof of which it may be stated that licenses to manufacture malleable iron under the patent were purchased by ironmasters to the extent of £25,000 in less than twenty-five days from the reading of the Cheltenham paper. Great excitement existed at that moment in the iron trade, and many persons seemed to covet a share in an invention that promised so much; there was, consequently, a general rush to the patent office, each one intent on securing his supposed improvement. It was thought scarcely possible that the original inventor should at the very outset have secured in his patents all that was necessary to the success of so entirely novel a system, he must surely have overlooked or forgotten something; perhaps even left out all mention of some ordinary appliance too well understood to really need mentioning; so in the jostle and hurry to secure something, any point on which a future claim could be reared was at once patented. Some of these gentlemen even re-patented portions of the writer's own patents, while others patented things in daily use, in the hope that they might be considered new when added to the products of the new process.

Within six weeks of the date of the Cheltenham paper, Mr. Robert Mushet had taken out three patents, which form part of that long series of patents by which he hoped to secure to himself the sole right to employ manganese in combination with iron or steel made from pig iron by forcing atmospheric air through it. In this long series of patents almost every conceivable mode of introducing manganese into the metal is sought to be secured. It was claimed if used in combination with pitch, or other carbonaceous matter; it was claimed if simply used in the metallic form, or, as Mr. Heath calls it, a carburet of manganese; it was also claimed if combined with iron and carbon—as in spiegeleisen. Manganese, in any of these states of combination, was claimed if put in with the metal prior to the commencement of the process; it was claimed if put in during the continuation of the process, and claimed if added to the steel after the process had been completed; it was also claimed if put into any furnace, crucible, or vessel, that the converted metal might be run or poured into; in fact, manganese and its compounds were so claimed under all imaginable conditions, that if this series of patents could have been sustained in law it would have been utterly impossible for the author to have employed manganese with steel made by his process, although it was considered by the trade to be impossible to make steel from a coke-made iron without it.

In the *Mining Journal* of September 24th, 1853, just four years before the first of Mr. Mushet's series of patents, a letter

* See this Journal, vol. xxiv. p. 179.

was published on the subject of Heath's invention. The writer of that letter says—"I am a steel maker, and deny that steel was ever made with the addition of carbon and manganese or carburet of manganese previously to Heath's invention, and I confidently assert that no cast steel maker can now carry on his business to profit without the aid of carburet of manganese. There are," he says, "a hundred methods of improving steel with manganese, but they all involve the same principle. Put carbon and manganese into the steel pot in any form you please and at any time you like, and if the steel be thoroughly melted the carburet of manganese melts also and is alloyed, and the improvement is unerringly effected, and by the use in every instance of carburet of manganese."

This letter clearly shows how well the subject was understood in the steel trade thirteen years ago.

Very soon after the reading of the Cheltenham papers, several rough trials of the Bessemer process were made privately by persons in the iron trade, and defects discovered which were supposed by practical men to be perfectly fatal to the invention. Once more the press teemed with accounts of the process, but this time it spoke only of its utter impracticability, and of regrets that the expectations originally formed were so fallacious. The storm, however, gradually subsided, and the process and its author were soon entirely forgotten. Imperfections in the process there certainly were, but the author had had the most irrefragable proofs of the correctness of the theory on which his invention was based, and also that the reasoning on which it was so utterly condemned by the trade was in itself wholly fallacious; he therefore decided not to argue the question against a hundred pens, but to energetically prosecute his experiments, and to remain silent until he could bring the process to a commercial success. When, at the expiration of about three years of incessant labour on the part of himself and partner, Mr. Longsdon, and an expenditure of more than £10,000, the process was again brought before the public, not the slightest interest was manifested by the trade; it had been for years agreed on all sides that it was a total failure, and was looked upon simply as a brilliant meteor that had suddenly flitted across the scientific horizon, leaving the subject in more palpable darkness than before. This entire want of confidence on the part of the trade was most discouraging; one of two things became imperative, either the invention must be abandoned, or the writer must become a steel manufacturer; the latter alternative was unhesitatingly accepted, and Messrs. Henry Bessemer and Co. determined to erect a steel works at Sheffield, in the very heart of that stronghold of steel making. At these works the process has ever since been successfully carried on; it has become a school where dozens of practical steel makers received their first lessons in the new art, and is the germ from which the process has spread into every state in Europe, as well as to India and America.

By the time the new works at Sheffield had got into practical operation the invention had sunk so low in public estimation that it was not thought worth paying the £50 stamp, due at the expiration of three years, on Mr. Mushet's large batch of manganese patents; they were, consequently, allowed to lapse and become public property.

The author has, therefore, used without scruple any of these numerous patents for manganese, without feeling an overwhelming sense of obligation to the patentee.

At the suggestion of the author a works for the production of manganese alloys was erected by Mr. Henderson, at Glasgow, who now makes a very pure alloy of iron and manganese, containing from twenty-five to thirty per cent. of the latter metal, and possessing many advantages over spiegeleisen, which it will doubtless replace. Two bright rods of 1⅛ in. diameter will be found on the table, they were folded up cold under the hammer. This extremely tough metal is made by using Mr. Henderson's alloy in lieu of spiegeleisen, which is incapable of making steel of such a quality.

A Prussian gentleman, M. Preiger, has been also successful in manufacturing a new alloy, which he calls ferro-manganese, consisting of sixty to eighty per cent. of metallic manganese. It is extremely useful in making malleable iron by the Bessemer process, in which spiegeleisen cannot be employed on account of the large proportion of carbon it contains.

It is gratifying to turn from a review of the troubles and impediments of the past, and briefly notice some of the more important applications of steel as a substitute for wrought-iron.

In no case is this change of material more important than in the construction of ships, for in no instance are strength and lightness more essential.

The Bessemer cast steel made for ships' plates by the several eminent firms now engaged in that manufacture, is of an extremely tough and ductile quality, while it possesses a degree of strength about double that of the inferior kind of iron plates usually employed in shipbuilding, hence it is found that a much less weight of material may be employed, and at the same time a greater degree of strength may be given to all parts subjected to heavy strains.

Most prominent among the builders of steel ships is the firm of Jones, Quiggin, and Co., of Liverpool, who have now constructed no less than 31,510 tons of shipping, wholly or partially built of steel. Of these, thirty-eight vessels are propelled by steam with an aggregate of 5910-horse power, besides this the principal masts and spars of eighteen sailing ships have been made by them wholly of steel.

Vessels of a large size, constructed to class AA twelve years at Lloyd's, weigh, when built of iron, about 12 cwt. per ton measurement; whereas similar vessels built of steel weigh only about 7 cwt. per ton measurement; thus an iron ship, to take first-class at Lloyd's for 1000 tons measurement, would weigh 250 tons more than a steel one of the same class. Such a vessel could, therefore, take 250 tons, or 25 per cent. more freight at the same cost, or could avail herself of the difference of immersion to leave or enter port when the tide would not permit an iron vessel to do so. As a steamer she would carry 250 tons more of coal, and thus be enabled to lengthen her voyage or take her coal for the return trip. The two steel paddle-wheel steamers launched at Liverpool by Messrs. Jones and Co., on the 13th ult., for Dublin and Liverpool service, will draw from 3 ft. to 4 ft. less water than iron steamers built on the same lines, and being thus enabled to leave port at all states of the tide, will not require a tidal train in connection with them. If the employment of steel for the construction of merchant vessels is found to be so important, how much more so is it for ships of war. Some of the larger class of armour-plated vessels require 6000 tons of iron for their construction, and an addition of 1800 tons in the shape of 4½ in. armour plates. Now, if the frames and inner skin of such a vessel were constructed of steel, it would be much stronger even if reduced to 4000 tons in weight; this would admit of 9 in. armour plates being used in lieu of 4½ in., and would still leave the vessel 200 tons lighter than the present ones; and hence, as the resistance of the armour to impact is as the square of the thickness of the plate, we should have a vessel capable of resisting four times the force of those at present constructed, while it would be 200 tons less in weight.

These important facts have not escaped the attention of Mr. Reid, our present talented constructor of the navy, and we shall, doubtless, soon have substantial proof of what may be effected by the employment of steel in the construction of ships of war.

The application of steel for projectiles has now become a necessity since the introduction of armour plates. We have before us a 110 lb. shot, that has passed with very slight injury through a 5-inch armour plate, and also some specimens of bent angle iron, made of Bessemer iron, and rolled at the Millwall Ironworks, in London, and from the same works a portion of one of Hughes' patent hollow steel beams for supporting the armour plating in course of construction for the forts at Cronstadt; both these are interesting examples of what the rolling mills of the present day can effect, and of the facility with which cast malleable iron and cast steel admit of being worked into the most difficult forms.

There is no department in engineering in which the peculiar toughness of steel, and its strength and power of resisting wear and abrasion, are of such vital importance as in its application to railway purposes. This fact had long since impressed itself strongly on the mind of Mr. Ramsbottom, of the London and North-Western Railway, who commenced experiments with this material in 1861; carefully, though trustingly, he tried it step by step, not even at first venturing to employ it for passenger trains, but as proofs of its safety and economy crowded upon him, he carefully applied it to the most important parts of passenger engines, and even to the manufacture of the formidable engine cranks (at that time entrusted only to the most eminent iron making firms in the kingdom), these iron cranks are now being replaced by steel ones forged from a single mass. One of these steel cranks, manufactured at the new steel works at Crewe, has been obligingly lent by Mr. Ramsbottom as an illustration of the use of steel for this purpose; that gentleman has also taken out of use a plain steel axle that has run a distance of 112,516 miles, and now exhibits very slight signs of wear.

The tires of wheels, on which so much of the public safety depends, were then tried, but the exact amount of difference between the endurance of wrought-iron and Bessemer steel for this purpose is not yet ascertained, as none of these steel tires are yet worn out; but enough has been shown to prove the advantage of entirely replacing iron by steel for this purpose.

In order to show how a steel tire will resist the most violent attempts to produce fracture, an example is given of a steel tire manufactured by Messrs. Bessemer and Co., of Sheffield; it was placed on edge under a six-ton steam hammer, and subjected to a series of powerful blows until it assumed its present form, that of a figure of 8, a degree of violence immensely more than it could ever be subjected to in practice. These tires are made without weld or joint, by forging them from a square ingot, partly under the improved plan invented by Mr. Ramsbottom, and partly by an improved mode of flanging and rolling, invented by Mr. Allen, of the Bessemer Steel Works, Sheffield.

So important were found to be the advantages of employing cast steel as a substitute for wrought-iron at the works of the London and North-Western Railway Company, that the directors, acting under the advice of their able engineer, determined on building a large steel works at Crewe, which is now in active and successful operation. In the design and arrangement of their plant for working up the steel several important improvements have been introduced by Mr. Ramsbottom, among others his duplex hammer, which strikes a bloom on both sides of the ingot at once, in a horizontal direction, and thus renders unnecessary the enormous foundations required for ordinary hammers. Here also, he has put up his improved rolling mill for rolling blooms of large size, the enormous machine being reversed with the greatest rapidity and ease by the attendant, without any shock or concussion whatever.

While matters were thus steadily progressing in the engine department of the company, the engineer of the permanent way, Mr. Woodhouse, took in hand a thorough investigation of a no less important problem—viz., the substitution of cast steel for wrought-iron railway bars. For this purpose some 500 tons of rails were made, and put down at various stations where the traffic was considerable, so as to arrive, at the earliest period, at a true comparison of the respective endurance of wrought-iron and cast-steel rails. It will be unnecessary here to enter into the numerous details of the extensive series of experiments systematically carried out by Mr. Woodhouse; the trials made at Camden will suffice to show the extraordinary endurance of steel rails. It is supposed that there is not one spot on any railway in Europe where the amount of traffic equals that at the Chalk-farm bridge at Camden-town. At this spot there is a narrow throat in the line, from which converges the whole system of rails employed at the London termini of this great railway. Here all passenger, goods, and coal traffic have to pass; here, also, the making up of trains and shunting of carriages is continually going on. At this particular spot two steel rails were fixed on May 2nd, 1862, on one side of the line, and two new iron rails were on the same day placed precisely opposite to them, so that no engine or carriage could pass over the iron rails without passing over the steel ones also. When the iron rails became too much worn to be any longer safe for the passage of trains, they were turned the other way upwards, and when the second side of the rails were worn as far as the safety of the traffic would allow, the worn out rail was replaced by a new iron one—the same process being repeated as often as was found necessary. Thus we find, at the date of the last report, on March 1st, 1865, that seven rails had been entirely worn out on both faces. Since then another has been worn out up to July, making sixteen faces worn out, the seventeenth face being in use on August 22nd, when the steel rail that had been placed opposite to them was taken up in the presence of the writer, and, by the kind permission of Mr. Woodhouse, now lies on the table before the meeting. The first face of the rail only has been used, and this is now become much thinner than it was originally, but, in the opinion of the platelayers, is still capable of wearing out another half dozen faces. Taking its resisting powers at three more faces only, it will show an endurance of twenty to one in favour of steel.

Mr. Woodhouse has ascertained, by careful and continued testing for twenty-four hours at a time, that an average of 8082 engines, tenders, or carriages pass over the steel rails every twenty-four hours, equal to 16,164 wheels every day for 1207 days, making a total of 9,754,974 wheels passed over the rail. Subject to this excessive wear the rail appears to have been reduced 7½ lb. per yard, hence, for every grain in weight of steel lost by abrasion, no less than 371 wheels had to pass over it. Another steel rail, put down also in May 1862, at a place much less subject to wear, has had four faces of iron rails worn out opposite to it, and still appears as if very little used; this rail is also placed on the table. An iron rail wears out by the giving way at various parts of the imperfectly welded mass, and not by the gradual loss of particles of metal, as in the case of the steel rail, which no amount of wear and tear seems capable of disjointing. It must be borne in mind that this enormous endurance of cast-steel is not owing to its hardness or brittleness, as some have supposed, for, in fact, Bessemer steel possesses an extreme degree of toughness. There is before the meeting an example of this fact: one of the same quality of steel rails having been attached at one end to the main driving shaft of a steam engine, so as to twist it while cold into a long spiral, measuring 9 feet in length at top and bottom, and only 6 feet if measured along the centre of the web. A single glance at this spiral rail will, it is presumed, dispel any idea of brittleness that may have been entertained.

In conclusion, it may be remarked that cast-steel is now being used as a substitute for iron to a great and rapidly increasing extent.

The jury reports of the International Exhibition of 1851 show that the entire production of steel of all kinds in Sheffield was, at that period, 35,000 tons annually, of which about 18,000 tons were cast-steel, equal to 346 tons per week; the few other small cast-steel works in the country would probably bring up this quantity to 400 tons per week as the entire production of cast-steel in Great Britain. The jury report also states that an ingot of steel, called the "monster ingot," weighing 24 cwt., was exhibited by Messrs. Turton, and was supposed to be the largest mass of steel ever manufactured in England. Since that date a great change has been made, for the largest Bessemer apparatus at present erected in Sheffield, at the works of Messrs. John Brown and Co., is capable of producing with ease every four hours a mass of cast-steel weighing 24 tons, being twenty times larger than the "monster ingot" of 1851.

There are now seventeen extensive Bessemer steel works in Great Britain. At the works of the Barrow Steel Company 1200 tons per week of finished steel can easily be turned out, and when their new converting house, containing twelve more five-ton converters, is completed, these magnificent works will be capable of producing weekly from 2000 to 2400 tons of cast-steel. There are at present erected and in course of erection in England no less than sixty converting vessels, each capable of producing from three to ten tons at a single charge. When in regular operation these vessels are capable of producing fully 6000 tons of steel weekly, or equal to fifteen times the entire production of cast-steel in Great Britain before the introduction of the Bessemer process. The average selling price of this steel is at least £20 per ton below the average price at which cast-steel was sold at the period mentioned. With the present means of production therefore, a saving of no less than £6,240,000 per annum may be effected in Great Britain alone, even in this infant state of the Bessemer steel manufacture.

Reviews.

A Treatise on Gas Works, and the practice of Manufacturing and Distributing Coal Gas. By Samuel Hughes, C. E. Second edition, with illustrations: revised by W. Richards, C. E. London: Virtue Brothers & Co.

The second edition of a small manual on gas works and the practice of manufacturing and distributing coal gas, originally written by Mr. Samuel Hughes, has just been published. This edition is said to have been revised by Mr. Richards, formerly of the Chartered Gas Works, and lately manager of gas works at Barcelona, but, in point of fact, it has been nearly re-written, for little of the original remains, with the exception of the first and last chapters. The manufacture and supply of gas has now become so important a matter, and it is conducted on such an extensive scale, that the construction of the various kinds of apparatus employed and the processes of distilling the coal and purifying the gas require so large an amount of engineering and mechanical skill and of chemical knowledge, as to raise what was formerly regarded merely as a simple mechanical art to the rank of a science. In this manual the subject is treated in a summary manner, without entering much into detail, but it conveys a sufficient knowledge of the mode of making and supplying gas to serve the purpose of the general reader; and it contains much information also that will be found valuable to the engineer, and to those engaged in any of the many operations now requisite for the erection of a gas work. To show the magnitude of the scale on which such operations are now conducted we may state, there is at present in the course of construction at the works of the Imperial Gas Company at Fulham, under the management of Mr. Kirkham, a gasholder of the diameter of 230 feet, which, when completed, will contain the enormous quantity of four million cubic feet of gas. It may be well conceived that in the excavation of the tank for such a gasholder, and in the construction of the ironwork, a great amount of engineering skill is requisite, and that many minute circumstances must be attended to, without regard to which the whole might prove a failure. In the early days of gas lighting, Sir Humphrey Davy observed, sneeringly, to Mr. Clegg, that he supposed they would want to convert the dome of St. Paul's into a gasometer, little dreaming that in the course of half a century many gasholders would be made far surpassing the dome of St. Paul's in internal dimensions. To give some idea of the many matters that require to be attended to before gas can be manufactured and supplied to our houses, it will be only necessary to recapitulate some of the subjects treated of in the various chapters of this work. They comprise, the chemistry of gas lighting,—the carbonisation of coal,—the retort house and buildings,—the retorts,—retort settings,—the hydraulic main,—the purification of gas,—the gasholder,—the exhauster,—gas meters,—laying mains and sewers,—pressure indicators and regulators,—burners,—residual products of distillation; and other processes and apparatus, in all of which chemical science and mechanical skill of a high order are brought to bear, to enable the gas companies to supply gas of the illuminating power and purity, and at the price we now obtain it, though we are ready enough to grumble at its quality and cost. There is no doubt that it might be better and cheaper, for in Liverpool gas of double the illuminating power of that supplied in London, is sold at three-fourths the price; but such an enviable state of gas supply has only been attained by exceptional circumstances combined with most excellent management; and it is some satisfaction to think that in the Metropolis, where coal and labour are dearer, improvements in quality and reduction in price have been and are in progress.

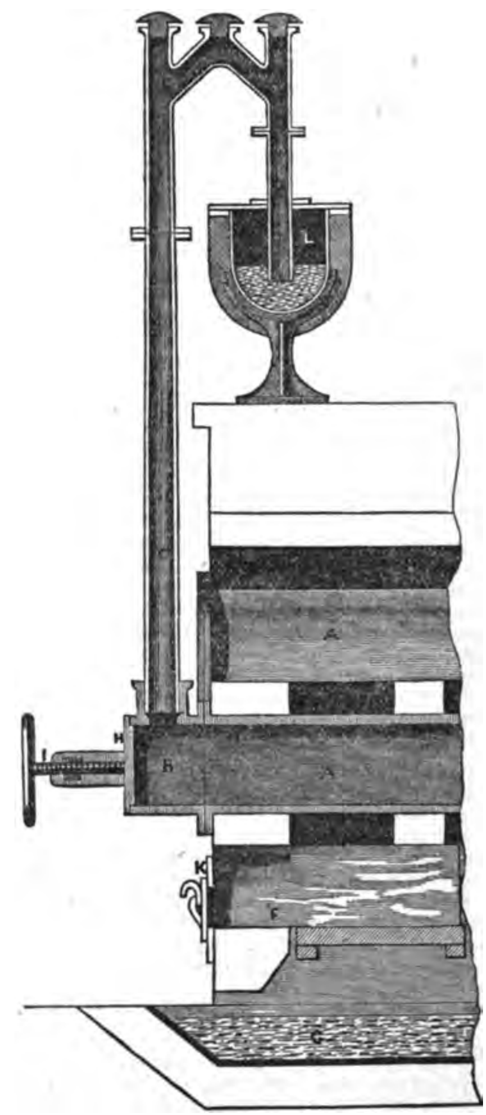
The original author of this treatise on gasworks has made himself known lately by his hostility to gas companies, and by inciting the local authorities in various parts of the kingdom to demand that the gas should be supplied to the public lamps at a lower price than to private consumers; and one of the means he usually advocates is, that the gas supplied should be measured by metre, one metre being fixed to every twelfth lamp. To ensure uniformity between the metred and the unmetred lamps, he enforces the use of a double tap, by the regulation of which to a given pressure he contends that the desired uniformity can be obtained. The introduction of the double tap is a great bone of contention between several gas companies and the local authorities; and as Mr. Hughes generally attaches so much importance to its use, it is remarkable that no mention whatever is made of the double tap regulator, in this second edition of what purports to be his treatise on gasworks.

Another of the points not touched on in this book is the difference that is caused in the pressure of gas when supplied at different levels. The difficulty of supplying gas to places below the level of the gasholder is one of the reasons for recommending that the site of gasworks should be on the lowest part of a town; but it is a curious fact that all gas engineers seem to entertain an erroneous opinion of the cause of the difficulty. They attribute it to the levity of the gas; for it is asserted that as coal gas is much lighter than atmospheric air, it must rise in the mains and pipes, and rush out with more force at greater elevations than in lower places. In this opinion, however, we contend they are entirely mistaken. The *pressure within the mains* would be the same at all points, when no gas is being supplied, and were there no leakage. The difference between the pressure inside the mains and outside at different elevations depends, we believe, altogether on the diminution of atmospheric pressure at high levels. At a height of 200 feet the difference would amount to a pressure equal to about 4 inches of water, and that is more than sufficient to account for the difference experienced in the pressure of gas at various elevations. We shall perhaps return to this subject on a future occasion, and shall now subjoin a few extracts from the treatise on gasworks, describing the process of distilling coal for the production of gas:—

Carbonisation or Distillation of Coal.

"The first process in gas manufacture consists in submitting the coal to the action of a high heat, whereby its destructive distillation, or as generally termed carbonisation, is effected. In practice, this is done by placing the coal into retorts of fire-clay or iron, which are previously heated considerably above its point of ignition.

The retort being charged with coal, is then hermetically closed with a door and luting, leaving no means of escape for the gas, except through the ascension pipe. By these means the coal is decomposed, and the gas evolved, and when effectually done the residue left in the retort is simply coke—a substance chiefly consisting of carbon, containing neither bitumen, tar, nor other volatile matter capable of yielding a useful gas for the purpose of lighting.



The gas expelled from the coal passes from the retort A (Fig. 1), up the vertical pipe, called ascension pipe, C; then traverses the bridge, or H-pipe D, down the dip pipe E, into the hydraulic main L—which is a large tube placed horizontally, and extending along the length of the furnaces. B is the mouthpiece attached to the retort; H is the lid or door of mouthpiece; J, the screw for securing the same; F, the furnace; K, the furnace door; and G the ash or evaporating pan.

The hydraulic main is about half filled with water or tar, into which the ends of each and all the dip pipes are immersed, and the gas, as generated, forces its passage through the liquid into the space above, but cannot again return into the retorts; so that when once arrived in the hydraulic main, it is fairly secured, and ready for the operation of purification.

The reason of this is very simple—for the heat, in expelling the gas from the coal, by the vastly increased volume, creates a pressure or force similar to that of steam when generated from water, the two processes being identical. This pressure being superior to the obstacles which oppose the passage of the gas, such as the dips of the hydraulic main, scrubbers, purifiers, gasholder, and atmospheric pressure, the gas in consequence passes freely as generated; and the column of liquid in the hydraulic main and dip pipe being considerably greater than the pressure of the gas when in the holder, it is thus prevented from returning to the retort.

In the manufacture of gas, the proper means of carbonising coal is of the first importance; ignorance on this point has often entailed considerable and serious loss, when, by a little intelligence, proportionate profits would have resulted. To ensure the necessary degree of heat for the retort is of the utmost consequence.

With reference to the heat which it is proper to employ in the distillation of coal for gas-making, it is unfortunate that science has not yet furnished the practical man with any convenient method of estimating high temperatures. Wedgwood's pyrometer, though extremely ingenious, gives all its indications on so small a base line as to require an accuracy and homogeneity in the composition of the clay cylinders employed which is physically impossible. The range of temperature indicated by the Wedgwood pyrometer being more than ten times greater than the range from the freezing to the boiling point of water, has to be expressed within the limits of only ⅜ths of an inch, this being the extent to which a cylinder of clay contracts between a faint red heat at about 950° Fahr. and the melting point of cast-iron at 2800° Fahr. It is true this very small range of ⅜ths of an inch, divided as it is into 240 parts, is made appreciable by Wedgwood's contrivance of reading off on a base or ruler about 2 feet long, but the delicacy of observing and manipulating with such an instrument is too great to render it available for practical purposes, besides which the cones or cylinders of clay can never be procured sufficiently uniform in structure.

Daniell's pyrometer is, perhaps, superior to any other that has been tried. Its indications are caused by the expansion or contraction of a bar of platinum connected with a lever which acts as an index. The dial on which the index revolves affords room for a greatly increased space to read off the results, but this instrument for practical use is liable to some of the objections against Wedgwood's pyrometer. The recent methods pointed out by Mr. Prinsey for determining high pressures, by means of fusing the metals and their alloys, is far too troublesome and complicated for practical use. The beautiful experiment of obtaining the temperature of a furnace by means of thermo-electric currents is also far too delicate for ordinary use, and until some contrivance more capable of being reduced to daily practice shall be introduced into gas-making, we must be content to be guided in a great measure by the colours presented by the interior of the furnace.

Coal when submitted to a temperature approaching to 600° Fahr.—that is, a very dull red heat as seen in the dark, a degree of heat which slowly chars paper, but does not inflame it—its volatile matter is resolved into tar and oil, and little or no gas is evolved.

Mr. Young, of Bathgate, turned the knowledge of this simple fact to very great advantage, by decomposing Boghead cannel coal at that degree of temperature whereby oil and tar only are obtained, which are afterwards purified, and universally known as paraffin oil. When the operation is properly conducted, the quantity of gas evolved is very small, in some cases perhaps not exceeding 50 feet or 100 feet per ton, the rest of the volatile constituents being condensed into liquid.

In the carbonisation of coal, in proportion as the heat of the retorts increases, so is the quantity of gas augmented, and the tar diminished. The best temperature for iron retorts compatible with their durability and good yield of gas, ranges from 1650° to 1800° Fahr., being cherry-red and bright cherry-red; but with clay retorts, a temperature between dull and bright orange, or 2100° Fahr., is the most suitable, giving vastly superior results in the production of gas than can ever be attained by the use of iron retorts.

Iron retorts, when worked at a low temperature, are of very considerable durability; in this state no deposit or incrustation takes place in them; but these supposed advantages are often dearly purchased. The attention of the writer was once called by a gas manager to the great durability of his iron retorts, which had been in use upwards of fifteen months, had never required clearing of carbonaceous deposit, and were almost in as good condition as when first fixed. This was all substantially correct; but on referring to the accounts, the yield of gas was ascertained not to have exceeded 6500 feet per ton; whereas by an alteration of furnaces, so that the proper temperature for the retorts could be attained, the yield was afterwards 9200 feet per ton. By the low temperature a large portion of the coal was converted into tar, and this in the locality being nearly valueless, the enormous loss can be readily understood.

As stated, the most advantageous degree of heat for carbonising coal is about 210° Fahr.; but when iron retorts are heated above 1800°, they are speedily destroyed, or "burnt out." Clay retorts, on this account, have an immense superiority; they can be heated to the proper temperature without the risk of injury; they are of extraordinary durability (their average duration in some works being four years); the quantity of coal carbonised by them is considerably greater, and labour less than when iron retorts are used. These combined circumstances have caused clay retorts to entirely supersede those of iron.

The time the coal remains in the retort is called the charge; thus, if subjected to four hours' distillation or carbonisation, it is termed a four hours' charge; if for six hours, a six hours' charge. The word charge also applies to the quantity, as when a retort is supplied with a certain weight of coal, say 140 lb. or 2 cwt., as the case may be; they are respectively called a charge of 140 lb. or a charge of 2 cwt.

The nature of the coal must regulate the quantity and duration of the charge. Some descriptions, as cannels, yield the gas very rapidly; so in Scotland, where this is very generally used, it is found necessary to have small charges of about 1¼ cwt. per retort, or less, which is drawn every three hours. With Newcastle coal, which does not yield its gas so readily, 2¼ cwt. are very common charges, which is worked off sometimes in five hours, but more generally in six hours.

The coals destined for carbonisation should always be in a dry state; and when by accident they are otherwise, if possible they should be placed along the retort-house and opposite the beds in use, some hours before required, in order to dry them. In addition to the evils of wet coals already enumerated, according to the opinion of Mr. Lewis Thompson the steam is converted into hydrogen, thus impoverishing the gas; but however correct this may appear in theory, from my own observation it does not occur in practice, the heat to which the steam is exposed being insufficient for its decomposition.

The magnitude of the works must aways decide the mode of operation. In large establishments, where double retorts are used, being open at both ends, a double set of men is required to work them so as to be enabled to charge the two ends simultaneously. The economy of this, over the old method of setting the retorts back to back in different ovens, is very considerable.

When double retorts are used, each end is worked with at least three stokers, and an extra man for preparing the lids of the mouthpieces. Others are required for extinguishing the coke, wheeling coal into the retort-house, clinkering furnaces, and attending to fires. Three stokers, assisted by a man to extinguish the coke, will perform all the work of taking off the lids, raking out the coke, extinguishing and wheeling it away from a bench of seven retorts, in twelve or thirteen minutes; they will then put the proper charge for each retort in the scoop, deliver its contents, and be ready for charging another bench in a further space of seven minutes, while a fourth workman will, in the meantime, have put on the lids, so that the whole work of discharging and charging the seven retorts will occupy barely twenty minutes.

This extreme dexterity is of course only acquired by long practice, and it must be admitted the labour is very severe; but this is moderated by the time the men have for repose between the charges. The first process, in discharging or drawing, is for one or two of the men to relieve the screws of the mouthpieces of the retorts about to be discharged, by giving three or four rapid turns; another man instantly gives a knock to each of the cross-bars to disengage them from the ears of the lid, and at the same time strikes the lid a blow with a piece of iron or hammer, in order to break the luting, and a light is immediately applied to prevent explosion, which would be likely to crack the retort if of clay. For want of this precaution, many lamentable accidents have happened through the gas exploding when combined with atmospheric air. The men then lift off the cross-bar and screw of each retort, placing them on the ground, and then each seizes hold of a lid in both hands, lifting by the projecting ears, and placing it aside to cool, ready for luting for another charge.

Three of the stokers than take up their iron rakes, which are simply rods of ¾-inch iron, about 12 feet long, having a handle at one end; the other being turned at right angles is flat, about 6 inches long, 2 inches wide, and ½-inch thick. These are inserted in the retort, and the red-hot coke drawn to the mouth, whence it drops into the coke vault, where there is a man ready to extinguish by throwing water on it; or when there is no vault the coke drops into iron barrows placed ready to receive it, and wheeled rapidly away when the charge is withdrawn. If the coke were not immediately extinguished it would smoulder, and the surface become covered with earthy ash, and detract from its appearance and value.

Formerly, in charging retorts, the operation being comparatively very protracted, there was a considerable loss of gas, in addition to the time and extra fatigue to the men. In order to remedy these inconveniences, a method has been contrived for depositing the whole charge in the retort at once; for this purpose an iron scoop is used, this being a semi-cylinder of sheet iron from 8 to 10 feet long and 10 or 12 inches diameter, with a cross handle at the end to assist in lifting and turning it round to empty the coals in the retort.

The charge of coal is placed in the scoop while it rests on the ground, having a bent rod underneath for the purpose of lifting it: one man takes hold of the cross handle, and two others lift the other end by the bent rod and introduce it into the mouth of the retort. The scoop with its contents is then pushed forward to the further end, turned completely over, and immediately withdrawn, leaving the coal in the retort, which is raked into a layer of uniform thickness, when the lid, previously luted and ready, is placed in its position and screwed up as quickly as possible. The operation of charging a retort with the scoop does not occupy more than thirty or forty seconds, so that very little escape of gas can take place. Hence the scoop has come generally into use wherever the works are large enough to supply three men for the purpose of working it. The composition for luting the retorts is made generally of the spent lime from the purifiers, mixed with a little fire-clay or loam, and well worked up with water like mortar. In large works it is prepared outside the retort house and brought in by wheelbarrows as required. In dressing the retort-lid with the luting, the workman uses a trowel, and works a little of it up on a board, and applies it all round the rim, taking care previously to clear off the old luting.

In small works, which do not permit of the necessary men being employed to work double retorts, single retorts, generally about 8 feet long, are used. These are charged by means of the shovel, and the process is necessarily more tedious than the scoop, and the expenses of labour for carbonisation increased.

The beds or ovens of single retorts in very small works are placed side by side, and extend the length of the retort-house. In works of larger magnitude they are placed back to back.

The number of men required to carbonise a given quantity of coal depends on the size of the works. At extensive establishments each man carbonises from five to six tons of coal per day, whilst in small works, where iron retorts are used, often 25 cwt. is not attained. In Scotland formerly, and perhaps at present, it was sometimes the custom for the stokers to be engaged by piece-work.

A very essential point in the carbonisation of coal is to keep the interior of the retorts free from incrustation, and, indeed, as far as possible, preventing it taking place. This incrustation, as already referred to, is a solidification of the richest parts (the heavy hydrocarbons) of the gas, and when gas is subjected to a high pressure and great heat, these are deposited in great abundance.

It also entails several other disadvantages—it increases the fuel and labour; by its obstruction renders more retorts necessary, so increasing the capital invested; and wherever it abounds the coke is always of inferior quality. In iron retorts, where the heats are not so high as in those of clay, supposing both to be subject to the same pressure, this deposit does not take place so speedily; but it is always in excess in the hottest part of the retort, which is generally the closed end, and diminishes towards the mouth in proportion to the diminished temperature. It has often been considered that the exhauster was unnecessary wherever iron retorts were used; but wherever the incrustation of carbon occurs, either in iron or clay retorts, it may be taken as a direct proof of the necessity of that instrument.

When clay retorts are at the most advantageous temperature, the gas having a pressure of 18 or 24 inches in them, which is not uncommon when no exhauster is used; two or three weeks are sufficient for a very inconvenient accumulation of carbon in the retorts; but when the pressure is diminished by the exhauster to about 1 inch, the same quantity of accumulation would require from three to four months.

The mode sometimes adopted to clear out this carbon (the furnace being heated as usual), is to project from a tube a small jet of steam on to the crust attached to the roof of the retort. The oxygen of the steam combines with the carbon which gradually diminishes, and when sufficiently thin can be easily detached by means of a chisel bar, it being removed from the roof, like an arch without the key; the deposit of the sides breaks away in large lumps.

Others prefer a periodical cleansing by leaving the retorts exposed to the action of the atmosphere, the heats being kept up as usual; for this purpose the door is placed in its position, leaving about an inch space between it and the mouthpiece. The air enters and gradually cleanses the retort. It is always advisable to clear out this deposit before it becomes too thick; if neglected, its accumulution is very rapid.

In all coal, combined with the ash, there are particles of iron, lime, and other substances, which fuse and become slag, or clinker, which deposits itself between the furnace bars and stops the current of air. To effectually remove this the bars should be loose, as hereafter stated; and the clinker is readily detached by means of a suitable bar.

When the ascension pipes are placed too close to the furnaces, or when the wall of the furnace is not sufficiently thick, the pipes are heated to such a degree that the tar in its passage is deposited thereon, as pitch, so causing a speedy obstruction.

Transactions of the Society of Engineers for the year 1864. London: E. & F. N. Spon, 1865.

In noticing the handsome volume now before us, we cannot refrain from making a few remarks with reference to the sterling and well-organised society whose proceedings it records. The Society of Engineers has, from the period of its first establishment in 1854, contained within itself the germs necessary for the attainment of a high position, although originally, and for a considerable time after its formation, it adopted a mistaken policy with reference to the too easy admission of new members, and the inadequate amount of subscription charged. The natural consequence of this was, that, although numbering among its members men of high talent and energy, the society naturally failed to take its due rank or assume its proper influence in the profession. All this has, however, been altered, and the society, by showing a fitting sense of what was due to itself, has induced a general feeling of confidence on the part of men of rank in the profession, who had previously kept aloof on the ground that the society held itself "too cheap."

In looking at this volume of Transactions, almost the first glance is sufficient to show, not only that it emanates from a body confident in itself as regards the present, but also determined not to be behindhand in the future in its representation of a profession the very essence of which is, and ever must be, progress. We accordingly find that the getting up of the volume is such as to bear favourable comparison with that of any existing institution, for not only is the size large and the type bold and good, but the numerous illustrative lithographs are remarkably clear and well executed, and are moreover printed with a blank space, so as to admit of their being referred to while the papers are being read.

The volume of the preceding year was undoubtedly well got up, but the present one is much in advance of its predecessor, showing clearly that the spirit of progress to which we have alluded is not only appreciated, but also acted upon by the council of the society. A valuable paper by Mr. Zerah Colburn, on "Certain Methods of Treating Iron in the Foundry," appeared in this Journal for May last, and was read before, and forms part of the Transactions of the Society for 1863; and the excellent paper by Mr. M. Parkes, on "The Wrought-iron Road Bridges of the Charing-cross Railway," which was given in the August number of the Journal, was also read before the society, and forms part of the volume of Transactions now under notice. These two papers may be taken as a sample of those contained in the two last volumes of the Transactions, and do the society great credit. Space will not at present permit of our entering in detail into the contents of the volume before us, but we commend it to the attention of our readers.

ADDRESS OF THE PRESIDENT OF THE MECHANICAL SECTION, BRITISH ASSOCIATION.

The President, Sir W. G. Armstrong, opened the business of the section by the delivery of the following address:—

Gentlemen, The Mechanical Section of the British Association is fortunate this year in having the annual meeting held at Birmingham. In no other town in the kingdom are mechanical and manufacturing processes carried on in greater variety, and the members of this section cannot fail to derive both pleasure and profit from the opportunity thus afforded them of witnessing these manifold branches of industry, and of discussing amongst themselves the various objects brought before them. Let it also be recollected that we are here on ground rendered classic by the labours of Watt. It was here that he reduced to practice those splendid mechanical conceptions, which have contributed more than anything else to the marvellous progress of the last half century. Every relic of the great mechanician which may here be presented, will excite reverential feelings in our minds, and we shall be especially interested in the collection of his original models, which I understand are to be submitted to our inspection at the *conversazione*, this evening, in the Town Hall. The papers to be read to the section embrace, as might be expected, matters of great interest and importance, and will, I trust, give rise to much instructive discussion. Nothing can be more surprising than the recent rapid and still accelerating progress of mechanical science, and assuredly this progress is in no small measure attributable to the facilities afforded by such occasions as the present for a more easy and general interchange of experience and ideas. Amongst the papers to be read, I notice one by Mr. Robinson, of Manchester, on the subject of that interesting and most curious apparatus, "Gifford's Injector;" and I anticipate that Mr. Robinson's experience will enable him to throw additional light upon this paradoxical machine. Should any obscurity remain, it will, I hope, be cleared up by the observations which this paper will call forth. The subject of hewing coal by machinery will be brought before the section by Mr. Levick. I refer to this subject with much satisfaction, not only on account of its importance, but also as being a successful step in mechanical science accomplished during the year which has elapsed since the last meeting of the British Association. It may be a matter of regret with some persons that the application of machinery to this and other similar purposes will operate to deprive labourers of their employment, but it must be admitted that whatever tends to economise human labour in the dark and dangerous recesses of a coal mine must be a benefit to the community; moreover, all experience has shown that, although labour may be diverted in its channels by the introduction of machinery, the aggregate amount of employment suffers no diminution, but on the contrary seems to increase. I regret that we are not also to have a paper on the progress which has been made in puddling by machinery, and I trust that, when another year has passed away, the President of this section will have occasion to notice the attainment of complete success in that desirable object. The paper from Mr. Bessemer upon steel, cannot fail to be highly valued by the section. The growing importance of this material, and its rapidly extending sphere of usefulness, have attracted attention in a special degree to the question of economy in its production; and certainly no one has contributed so largely as Mr. Bessemer to our advance in this direction. The various papers which are to be read on deep-sea telegraphic cables will prove peculiarly acceptable at the present moment, when our interest is so much engaged in the grand attempt to establish telegraphic communication between England and America. Never was there an undertaking which presented such formidable risks and difficulties at the outset; never were more discouraging failures experienced, and never were failures encountered with more indomitable courage and perseverance. Such enterprise as this reflects credit, not only upon the individual promoters of the undertaking, but also upon the nation itself. The paper promised by Mr. Cox upon Mr. Siemens's regenerative furnace will bring forward a subject the importance of which can in my opinion scarcely be over-estimated. Few people are aware of the prodigious waste of heat which takes place in all furnaces where it is requisite to communicate a high temperature to any material. If, for example, a mass of material is to be heated to a temperature of 2000° by flame of a temperature of 3000°, it is plain that the heating gases must, in the ordinary furnaces, escape at a temperature equal to that of the material, and thus carry off with them a heat which will, when the maximum temperature is attained, amount to two-thirds of the whole heat and combustion. The regenerative furnace arrests a large proportion of this fugitive heat, and adds it to the gaseous fuel which supports the combustion of the furnace. Wastefulness must always be deprecated in mechanical processes, but considering how much the greatness of this country is dependent upon her resources of mineral fuel, and with what prodigality we are now drawing upon these resources, any wholesale wastefulness demands especial reprobation, and renders the introduction of more economical methods of consumption a matter of national importance. The regenerative gas furnace not only prevents waste of fuel, but it also prevents smoke. Smoke may be altogether prevented, and is in fact inexcusable in the case of ordinary steam boiler furnaces; but I know of no means yet introduced by which its prevention can be effected in manufacturing furnaces heated directly by coal. If gas were substituted for coal, and the regenerative principle applied, the nuisance and disparagement occasioned by smoke would be entirely avoided in nearly all manufacturing processes. But the introduction of gas furnaces upon so large a scale must necessarily be a work of considerable time, and the system itself would probably require improvement and development to render it so widely available. I might extend my observations to the subjects of other papers to be read before you, all of which possess considerable interest, but I feel that little would be gained by such an extension of my comments, and that it is better for us at once to proceed to the proper business of the section.

After Sir W. Armstrong's address, several important papers were read in the Mechanical Section, some of which we lay before our readers *in extenso*, in this number of the Journal. They will be found useful contributions to our knowledge of the subjects treated, and will be read with interest.

THE NEGATIVE SLIP OF SCREW PROPELLERS.

The recent trials of the iron-clad frigate Bellerophon have resulted in one of the most extraordinary phenomena developed since the introduction of steam propulsion. For three days in succession this ponderous ship has been steaming about at the entrance to the Thames and Medway, under circumstances as yet unaccounted for, and which baffles those who have designed, built, and put engines into the ship, no less than the nautical men who had charge of her during her trials. The phenomenon in question is denominated "negative slip," but in common parlance it is spoken of as a case of the ship overrunning the screw, which in this instance has occurred to an altogether unexampled degree. Although throughout the trials of this ship, while the screw propeller which drives her has been itself advancing with a speed barely, if at all, exceeding 12¼ knots per hour, the ship herself has been speeding through the water at a rate of 13¾ knots. If a phenomenon of this nature had occurred with a light vessel constructed with exclusive regard to fleetness it would obviously have been a singular circumstance, but for it to happen with an iron ship of war of the stoutest construction, covered with the most ponderous armour ever yet applied to a seagoing ship, and carrying a greater weight of it on a hull only 300 feet long than the Warrior carries on a hull nearly 400 feet long, is a most unexpected and unaccountable circumstance.

This over-run of the screw by the ship has happened before in a less degree, even in some of our iron-clad ships, but up to the present time people have steadfastly refused to believe in it, and have resorted to many ingenious devices by way of accounting for it. The first and most obvious explanation was to attribute it to errors of calculation or measurement; another was to attribute it to obscure tidal influences, and this was favoured by the circumstance that it has been most frequently observed on the measured mile at Stokes Bay, where two high and two low waters are said to happen each tide, the one resulting from that portion of the Atlantic tidal wave which finds its way through the Needles Channel at the west end of the Isle of Wight, and the other from the portion which flows in round the eastern end of that island. A further explanation was sought for in the fact that the screw propeller of a ship works in a wave of water which is following her, and which thus adds to the real speed of the screw through the water—an explanation which is untenable because it would require that screw ships with full after-bodies would give the best results in steaming, whereas it is well known that they invariably give the worst. But perhaps the most popular explanation of all is that of assuming that the blades of the screw propeller bend under the resistance of the fluid, and thus become for the time being different screws, having a greater velocity in advance than when at rest. This explanation appeared to receive an extraordinary confirmation in the Achilles, the first iron-clad frigate which was found to over-run the screw, for on docking the ship after her first trials it was found that the blades had actually bent forward and grazed the sternpost of the ship. The explanation proved insufficient, however, for on trying the ship again with stronger blades, the bending of which was out of the question, nearly the same overrunning of the ship was found to happen. In the case of the Minotaur also, the trials of which at Stokes Bay were recently reported in great detail in the *Times*, the speed of the ship somewhat exceeded that of the screw. The Achilles and the Minotaur are, however, extremely long ships, with water-lines as sharp as those of a river steamer, and the excess of the ship's speed over that of the screw fell in every instance short of a knot per hour.

It is the occurrence of the same phenomenon in a far greater degree in a short ship like the Bellerophon, and its repetition day after day under circumstances which set all the popular explanations at naught, that give the recent trials so much importance, and impose upon our shipbuilders and engineers the duty of thoroughly investigating and accounting for its existence. If, in addition to being a short ship, the Bellerophon had not possessed what in nautical parlance is known as a very "clean run" aft, the old explanation of the following wave might again have been adduced in this instance; but the form of the ship's after body is as tapering as that of the Minotaur, and is wholly incompatible with this mode of accounting for what has happened.

If this subject possessed only an abstract scientific interest we should not have taken this notice of it, but it exercises so practical and immediate an influence upon the speed of our ships that it is calculated to excite the most general interest among engineers and shipbuilders, and throughout the navy; for it is found that with screw propellers that thus lag behind the ships which they are driving, a most injurious drag is put upon the engines. The engines put into the Bellerophon are designed expressly to revolve rapidly, and the ship was taken down the river on trial with the understanding that the screw would have been turned round about 70 times per minute, thus developing 6000 indicated horse-power. Instead of this, to the astonishment and disappointment of everybody on board, and of no one more than the enginemakers themselves, who are men of the greatest eminence, the drag of the four-bladed screw was found to be so great that not even 60 revolutions could be secured, even when all idea of using the steam expansively was abandoned and it was allowed to rush with full force into and through the cylinders. A great waste of steam was thus of course occasioned, and consequently scarcely 5000 horse-power, instead of 6000, was developed. The wonder is that under such circumstances, the high speed of 13¾ knots was attained, and the fact that it was is the best possible guarantee that a speed of more than 14 knots will be secured in this remarkable ship when the full power of her engines has been developed with a different screw. The peculiarity of the screw at present applied to the ship is not limited to the number of its blades. Each of these four blades is formed with two faces standing at an angle of inclination to each other, in order that each half of it may impart a different velocity to the water, somewhat upon the principle of the differential screw propeller invented many years ago by Bennett Woodcroft, of the Great Seal Patent-office. The Bellerophon's screw really has eight blades, in fact, arranged in four pairs, and as the diameter of the whole is no less than 23 ft. 6 in., the drag which it puts upon the engines must be truly enormous. So far as we can learn, neither the designer of the Bellerophon nor the Admiralty approve such a propeller being applied to the ship, and after the trials of last week it is hard to believe that the engineers will care to insist upon its use. It is understood, however, that one other trial is to be made of it, with its blades set to a different pitch, as soon as possible, and if the result then secured be not satisfactory, a two-bladed Griffiths screw, like that of the Warrior, will be fitted to the ship. It is understood that this is what Mr. Reed would prefer, not only on account of the steaming qualities of the ship, but because of the serious obstruction to the speed of the ship under canvas which the four-bladed screw must necessarily present.

The Bellerophon will be a full-rigged sailing ship as well as a high-speed steamer; but it is not to be expected that any amount of sail-power would suffice to propel her rapidly through the water if subjected to the drag of a screw which lags so much behind the ship, even when it is itself the propelling agent. The extreme handiness of the Bellerophon under the action of her novel form of rudder affords the strongest possible inducement to disembarrass her as much as possible from the hindrance of an improper form of screw. Her rudder is on what is known as the "balanced principle," being pivoted near the middle instead of at its forward end, as usual. It is coming into use rapidly in America, and was tried in the Great Britain steamship in this country many years ago. For some cause or other however, it was prematurely abandoned, like many other useful things. With the exception of an experimental trial in a small gunboat at Devonport, under the direction of Capt. Astley Cooper Key, R.N., C.B., it has never before been applied to a British ship of war, and it certainly was a very bold experiment to apply it at once in so large and powerful a ship as the Bellerophon. That ship, however, being of iron, and very strongly built, afforded a really favourable opportunity for its trial on a large scale, and the success attained is most remarkable. It is true the Bellerophon has been designed expressly with a view to handiness, being made short, and of a light draught of water forward expressly for this purpose, and she would no doubt have steered remarkably well with an ordinary rudder. But it is to the adoption of the balanced principle that the extreme ease with which the helm is handled is due. On Friday last Capt. Randolph, R.N., who had charge of the ship, and Mr. Reed, themselves took the steering wheel with the ship at full speed, and steered her easily without assistance. At Portsmouth, on the Minotaur's trial, it required sixty men to put the rudder over 31 deg., and they were 1 m. 4 sec. in doing it. On Friday eight men put the Bellerophon's rudder over 37 deg. in 20 sec. The Minotaur, with sixty men, turned a circle in 7 m. 15 sec.; the Bellerophon, with eight men, turned it in 4½ minutes. The Minotaur turned the first half circle in 3 min. 47 sec.; the Bellerophon in 1 min. 50 sec.

Even these figures will scarcely enable the reader to fully realise the handiness of the new frigate; but few will be at a loss to understand it when it is stated that while the Admiralty have at length been compelled to build new and powerful steam-tugs in order to enable the Warrior and other long iron-clad ships to be got into and out of Portsmouth and Devonport harbours, the Bellerophon, after the completion of her trials on Friday, steamed, without the aid of tugs, not merely into Sheerness harbour, but pursued her way at a speed of $10\frac{3}{10}$ knots (by log) along the 14 miles of the river Medway's winding course, threading her way among the long succession of hulks which encumber that narrow and tortuous stream, never stopping her engines for a moment until she reached the sheer-hulk off Chatham Dockyard, to which she was secured for the night. This achievement was one of national interest, and much credit is due to Capt. Stokes, the master attendant of the dockyard at Chatham, who had charge of the ship after Sheerness was passed, for affording so striking an illustration of the steering capabilities of our latest iron-clad frigate.—*Times*.

RAILWAYS IN WAR.*

By Sir J. Burgoyne, K.C.B., F.R.S.

The use of railways will have an important effect in war, and it is a matter of interest to ascertain the means for obtaining the greatest advantages from them, and what then will be their precise capabilities.

A vague idea exists that armies can be transported from place to place, and to a seat of war, with the same facility and speed as ordinary travellers; whereas there are many circumstances connected with the conveyance of the former which would show any such comparison to be quite fallacious.

With regard to a small body of infantry there is no reason why this should not be the case, but with large forces, and with cavalry and artillery and all the accessories of an army—its baggage, camp equipage, spare ammunition, its waggons, &c.—enormous means will be required, and difficulties will arise which call for study and consideration to reduce them to a minimum.

How to adapt the ordinary railway passenger and horse carriages and trucks in the best manner to the transport of troops of all kinds, and how to get the troops most rapidly in and out of them, will be easily ascertained, if it has not been so already; the great desideratum is to find how large forces can be moved in greatest strength and with most rapidity on single railways, or by a limited number of lines—for it is on these calculations, having under consideration the several lines which can be brought to bear on the operations, that the generals in command must arrange their plans.

The basis for consideration will be, what can be done by any one line of railway with its ordinary means, or aided by additional means from other lines of the same gauge, with which it is connected on the same level, and which may not have the same pressure on them.

To afford an idea of what may be required, it may be assumed that the officers and soldiers will occupy the space of ordinary travellers, and consequently it becomes a question, how many passenger carriages in how many trains, each drawn by one locomotive, will be required to carry 1000 men, with their officers; and how many horses of cavalry, artillery, and for staff of infantry regiments, one truck will carry.

The guns and equipments of each battery of field pieces, with number of trucks necessary to convey them, should be defined, as well as the number of horses per battery of horse or foot artillery.

To give an idea of the amount of conveyance required for such forces on one occasion, to transport a battery of field pieces with its horses and carriages, and about 500 cavalry, merely to a review, no less than six trains were required, each consisting of thirty railway carriages.

Viewing then the very large means necessary for moving any but a very moderate force, and the embarrassments which would attend the undertaking, in the rapid succession required to be effective, it becomes a matter of much interest for railway engineers to consider and define how arrangements can be made in providing, stationing, and working the trains that will tend to facilitate the service, and what, with the adoption of these measures, would be the capabilities of conveyance of troops of given strength to given distances in given times, on emergent occasions, on any one railway; whether, for instance, as the great traffic is in one direction, both lines of rails might not be used for it for certain distances, under the best arrangements which can be made for the return carriages, &c.

These researches are required, not only to ascertain the best modes of accelerating the movements, but also to come to a clear understanding as to what, even when duly organised, can be obtained from railways in rapidity of transport for large bodies.

It is manifest that as they approach the scene of action the railways would have less influence on the immediate theatre of warfare itself; it would be somewhat dangerous to trust to them at all under the chance of the enemy interrupting the communication between the divisions and resources of the army.

For short distances there would rarely be much advantage, as regards time, in moving troops by them, on account of the time required for getting to and away from the railway, and into and out of the carriages.

Their great advantage would be for concentrating troops and means, by converging lines, from the interior to some appro-

* Read before the British Association.

priate point forming a basis of operations, for gradually bringing up reinforcements and other resources to the rear of the army, and for the speedy and better removal of sick, wounded, prisoners, and all incumbrances.

They will also be particularly favourable to retreating forces, by expediting their movements: while, by the destruction of the lines behind them, the enemy would be deprived of any use of them.

Every railway, even in the vicinity of the operations in a campaign, will be of much value so long as it can be used without danger of interruption; and therefore it becomes a subject of interest to possess a knowledge of the best means for their destruction, and how to apply them in cases where the lines are likely to fall into the hands of the enemy, or for re-establishing any that may have been more or less injured.

It is clear that a portion of a railway might be for hours in temporary possession of a part of an army who might, from ignorance or want of some trifling means, be unable to take advantage of the occasion, and thus would leave it to be re-possessed by its enemy in perfect order; when, by due instruction and a little preparation, an influential amount of damage might have been done to it.

The military engineers of an army have attached to them in the field a selected assortment of the most useful implements for the different services most frequently required of them, the proportions of which they vary according to the prospect of the nature of the approaching engineering operations—such as for sieges, entrenchments, destruction or repairs of roads and bridges, mining, &c.; and they are practised in the best modes of applying whatever means may be at hand for their purpose. To these must now be added what is applicable to the destruction and re-establishment of railways.

In damaging a railway, to impede the progress and available means of an enemy's army, the object will of course be to do as little injury to a great convenience of the country as is consistent with the primary consideration of crippling the military resources of the enemy for the time.

Should the exigencies of the period justify extensive damage, it will be done by blowing in tunnels, bridges, viaducts, or embankments, by mines and processes as practised by military engineers with regard to the old routes, to the extent that circumstances will allow and may admit.

The object for consideration however, here, is how the peculiarities of a railway can be dealt with to most effect, in a summary manner, with little time and small means. Taking it, then, as a question rather of dismantling than of destroying, the first measure would be taking up and disposing of the rails. This would be easy enough to a party of railway navvies, provided with their apparatus, but what we require is some instructions and practice given to soldiers how to do as much as possible with the smallest means.

Thus, instead of being as at present, from ignorance, perfectly helpless, they might be taught, under previous instruction, that even a few stray articles for implements, such as might be found in an adjoining house—as might be described—could, on an emergency, be made available to some extent: possibly it could be shown that, after a first rail was removed, the very article itself, with the sleepers, &c., might be used to extend the damage.

Another question will be, having in view the possibility of obtaining a temporary power over a railway which is of service to the enemy, what very small and most portable assortment of implements might be carried with any detachments being accompanied, if possible, by a few sappers, that would aid such a proceeding, and what would be the most effective process; and if the implements could be such as enter into the assortment forming part of the engineer field equipment required for other purposes, all the better.

The rails being raised, the best disposition of them would be clearly to carry them away altogether; but it is very improbable that there would be available means of conveyance to render that practicable. The next most easy resource would be to scatter, hide, or bury them; but if it could be shown how they could be broken, or rendered unserviceable, the effect would be still greater. The destruction of the sleepers would be much more easy, but the effect would be less; and the removal of the chairs, from their portability, would be easy, and also valuable for the object.

With regard to the reinstatement of a damaged line, it would be interesting to know whether any temporary expedients can be adopted for the passage of locomotives and carriages, or even of the carriages only, across the places where the rails may have been removed, till new rails can be procured; and if so, what those expedients may be, and how to be applied. One resource might be available in double lines, namely, to dismantle one of the double rows from the nearest part untouched, to make good a through communication for at least one single line.

It will be very desirable to obtain from railway engineers a consideration of all these matters, and special instructions drawn up on all the expedients that can be suggested, in which the troops—but more particularly the engineer soldiers—might be subsequently practised; nothing of the kind, it is believed, having yet been undertaken.

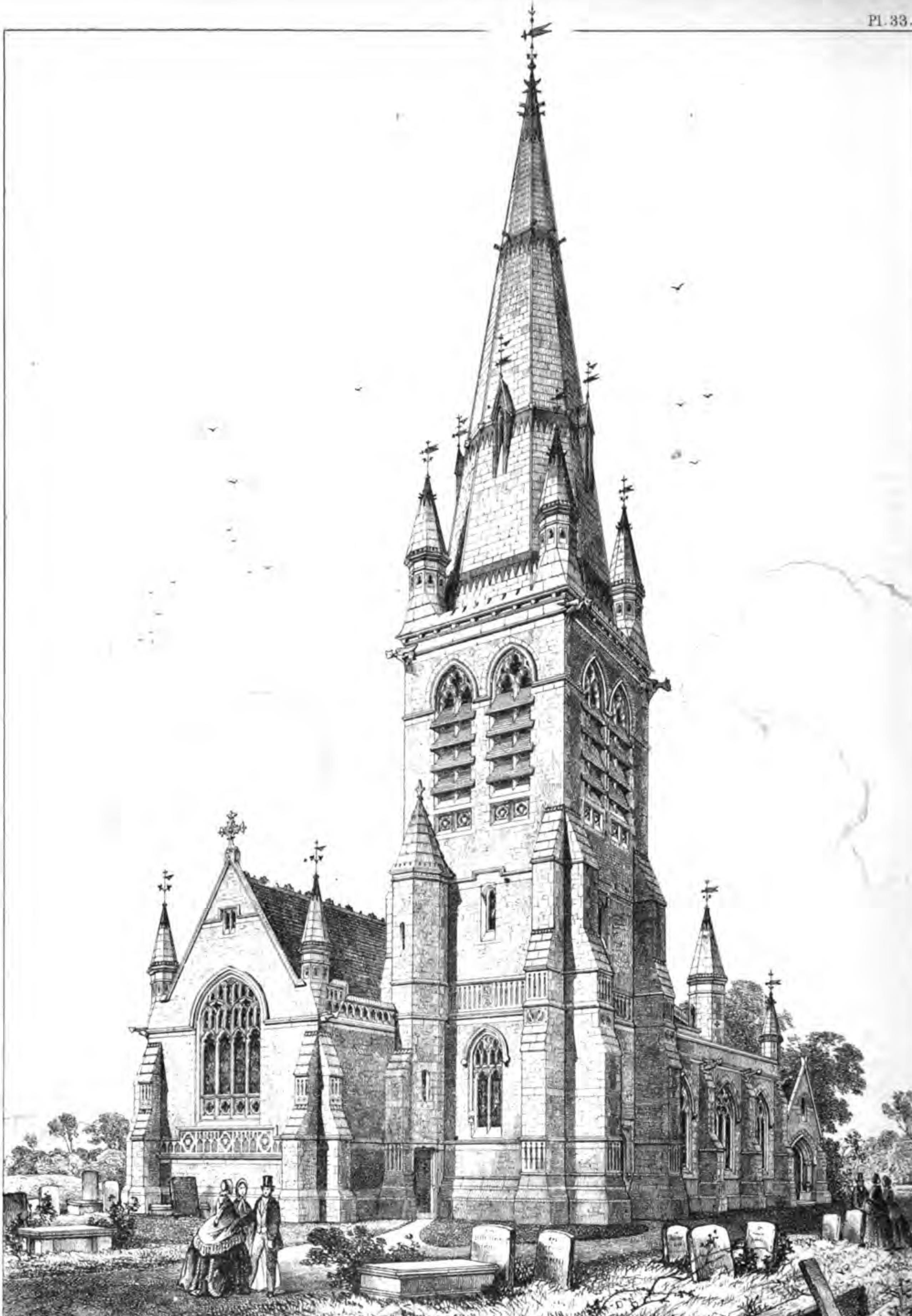
ON THE SECOND LAW OF THERMODYNAMICS.

By W. J. Macquorn Rankine, C.E., LL.D., F.R.S.

In this paper the author gives an elementary proof of the proposition (which in the Edinburgh Transactions for 1851 he had demonstrated by a lengthy algebraical process), that the "second law" of thermodynamics follows from the supposition, that sensible or thermometric heat consists in any kind of *steady* or stream-like molecular motion within limited spaces (as distinguished from unsteady motion, such as vibratory or wave-like motion, which is supposed to constitute radiance). The law in question is, that the quantity of energy converted between the forms of heat and mechanical power during a given change in the dimensions and condition of a body, is the product of the absolute temperature into a function of that change; and in it, and the first law (that of the convertibility of heat and mechanical energy) are summed up all the known phenomena of thermodynamics.

Concrete Arching.—The use of artificial stone and concretes in construction has been attempted in several forms, but generally in that of blocks previously shaped and afterwards applied like stones. In the extensive underground floors of a new barrack now erecting in Paris, the vaultings are being formed with what is called *Bétons agglomérés*, the exact composition of which is kept secret by the inventor, M. Coignet. The walls are full 13 feet apart, and the concrete is laid on timber centreings, and trodden and beaten down with great care. The vault and flooring thus formed is about 2 feet thick at the spring of the vaulting, but only about 10 inches on the crown, and it is found sufficiently strong for all practical purposes. It has also this advantage that the ceiling can at once be whitened, and the floor laid with tiles or cement without further preparation. The process is said to be successful and economical.

Mineral Statistics for 1864.—The statistical tables of the produce of the mines of the United Kingdom during the past year have been lately published, having been prepared under the direction of Mr. Robert Hunt, F.R.S. It appears that during 1864, 3268 collieries in Great Britain and Ireland produced 92,787,873 tons of coal. Of this quantity, 8,800,420 tons were exported, being an increase of 525,208 tons over the exportations of the preceding year. There were 2,351,342 tons brought to London in 1864, and 1,786,713 tons in 1863. 10,064,890 tons of iron ore were produced from the mines of this country, and there were imported 75,194 additional tons. The total quantity fed 612 blast furnaces, which produced 4,767,951 tons of pig-iron. There were exported 465,951 tons, and the rest was worked up at 127 ironworks, where 6262 puddling furnaces were in action and 718 rolling mills. The 192 mines in the South-West of England, and the 30 distributed over other parts of the United Kingdom, produced 214,604 tons of copper ore, which yielded 13,302 tons of metallic copper. The produce of lead ore, principally galena, was 94,433 tons, which yielded 91,283 tons of lead, and 641,088 ounces of silver. Of zinc ores, nearly all being the sulphide of zinc, 15,047 tons were obtained, producing 4040 tons of metal. Of iron pyrites, used in our sulphuric acid and soda works, there were procured 94,458 tons. The tin mines produced more tin in 1864 than in any previous year; 15,211 tons were raised, which yielded 10,108 tons of metallic tin. During 1864, gold was obtained from five mines in Merionethshire. These produced 2336 tons of auriferous quartz, which yielded 2887 ounces of gold; and it is stated that, in consequence of various improvements in amalgamation, due to Mr. W. Crookes, it is highly probable that the production of British gold will be considerably increased during the current year. The gross value of the foregoing mineral products was £39,979,837.



E. L. Blackburne, F.S.A. Arch^t J.R. Jobbins

WANGFORD CHURCH SUFFOLK. N.E. VIEW.

WANGFORD CHURCH, SUFFOLK.

(*With an Engraving.*)

In a former number, that for January 1864, we gave some account of the restoration and other works then lately effected in this church. Plate 33 in our present issue shows an exterior view of it—taken from the north-east—in its complete state. It was observed in our former notice that the present church of Wangford was originally that of the old Cluniac monastery of Wangford, and that considerable remains of the ancient priory were discovered when the late works were in progress. This was particularly the case as respects the church, the old plan and arrangements of which were very distinctly traceable. In the new works these have been as far as possible retained, or had reference to. The new chancel, of course, occupies—though somewhat increased in size, for the Anglo-Norman chancel appears to have been of no very great extent—the site of the former one. The tower also stands, if we may judge from the character of the old foundations here, as nearly as may be in the situation of a similar erection in the first church. This is, however, no further certain than that the old foundation here was of a heavier nature than in other parts, as if for the purpose of receiving a heavier structural weight.

The nave and the north aisle are preserved according as they were built and added to the earlier church about 1450-1480, the arcade between the two having been re-opened and relieved from the brickwork with which its easternmost arch had been filled up. The southern wall of the nave has been partly rebuilt, and two new windows inserted of the pattern of the old. Three very interesting flying buttresses on this side, which must have projected into the area of the priory cloister, have been also rebuilt according to their ancient form and detail, and the whole church otherwise restored according to the true and proper acceptation of the term. The old bells have been rehung in the tower, which from its position will form a conspicuous object in the surrounding landscape, more particularly on approaching Wangford from the Southwold and Blythborough-roads, in both of which cases it groups effectively with the Wangford schools, lately erected near the entrance to the village from the latter direction. A view of this latter building, designed by the same architect, was given in our number for October 1860.

IMPROVEMENT OF TOWNS.*

By James Lemon, A.I.C.E.

IV.—*Drainage* (continued.)

Ventilation of Sewers.—The ventilation of sewers is one of those subjects upon which a great many suggestions have been made, but still very few of them have been carried out. The system adopted in the Metropolis (excepting in the main drainage) is exceedingly primitive: it consists, as many persons well know, of a vertical shaft, about 3 feet square in the clear, built upon the top of the sewer, and covered at the top by means of two gratings about 2 feet by 6 inches each, flush with the surface of the road. The results of this arrangement are,—the smell from the sewage is allowed to pass up into the streets at a level where it is most objectionable; and the foul gases are inhaled by the persons passing; likewise, the gratings become choked with the mud and stones from the roads, or the bottom of the sewer becomes full of deposit washed or swept down the ventilators. In the main drainage system there is a cesspit about 2 ft. 6 in. square by 6 feet in depth under the ventilating gratings, which receives the detritus from the roads. This cesspit is connected with a vertical shaft adjoining thereto, built over the sewer in the same manner as the ordinary ventilating shafts. In the wall between the cesspit and the shaft there are two openings, one next the bottom fitted with a small iron grating, to allow the water to drain off, and to prevent the passage of stones &c. into the sewer; the other for ventilation, which is intended to be fitted with trays containing charcoal, so that the foul gases may be disinfected. In this method however the choking of the gratings is not remedied, therefore it cannot be considered one that can be recommended for general adoption.

The sewers of Paris are ventilated by means of iron pipes, which are connected with the branch sewers or house drains, and are carried up either in the thickness of the front walls of the houses, or outside the walls to the top of the roof. This plan, in some instances, has been objected to; but if the joints were screwed and securely fitted, the inlet connected with a charcoal filter in the sewer, and the outlet carried up above the roof of the house or adjoining building, there can be no reason why it should not be the best mode of ventilation that has yet been devised. One of the chief causes of complaint in Paris is the imperfect way in which the gullies or inlets for the street drainage are constructed: they are in some cases trapped, but the trapping is certainly not efficient, as the smell therefrom in some of the best parts of the city is very offensive.

Amongst the many modes of ventilation which have been proposed, there is one which might be easily adopted in the manufacturing districts, and that is to utilise, with consent of the owners, the tall chimneys, by connecting them with the ventilating shafts of the sewers; this would promote a current of air through the sewers, and draw off the noxious gases. Ventilation of sewers might also be effected by carrying up an iron tube in the centre of the lamp standards at the crossings of the main streets, similar to those in Southwark-street, London, the inlet being connected with a charcoal filter in the shaft from the sewer. This mode could not, from the isolated position of the outlet, be a nuisance to the occupiers of the houses in the locality, and would be an improvement on the present ventilators in the centre of the streets, flush with the surface of the roadway. Advantage might also be taken of the end walls at the corners of streets for carrying up ventilating tubes to the tops of the houses, as in Paris, so as to remove the objection to surface ventilation. A very curious mode of ventilation was suggested by Admiral Sir E. Belcher, which may be thus described:—the foul air was to be taken from the sewers by means of a pipe connected therewith, and carried up to the top of the lampposts, and there discharged. This rather novel way of mast-heading the stink, although it may be very nautical, might be objected to by persons occupying the first-floors of houses opposite the proposed outlet; in fact, the gallant admiral himself would find it somewhat unpleasant if he happened to be sitting at an open window to the leeward.

Side Entrances.—The side entrances to sewers should not be made as a rule more than 1000 feet apart; they bear a small proportion to the whole cost, and they are exceedingly convenient for repairs, making connections to house drains, cleansing, &c.; they should in every case be provided with a ventilator and cesspit, so that foul gases may not collect in the entrance shaft. The most convenient place for placing a side entrance is at the corner of a cross street, so that it may be available for access to the junction of the sewers at that point. Side entrances are usually constructed with an entrance shaft from 2 ft. 6 in. to 3 ft. square in the clear, with a horizontal gallery or chamber to the sewer about 6 ft. 6 in. in height, by the width of the shaft. A very useful size for the entrance shaft is 3 ft. by 2 ft. 6 in.. Iron ladders, for access thereto, are much preferable to foot irons, and are now being adopted in most modern works constructed by well-known drainage authorities. The entrance covers should be made as light as possible consistent with strength, and should be provided with wrought-iron gratings so constructed that both could be easily opened by one man from the *inside*. The cast-iron covers and gratings used under the Metropolitan Commisioners of Sewers are excessively heavy and clumsy, weighing between 4 and 5 cwt., so that if a workman should happen to be in the sewer and the flap become accidentally closed, he would be completely trapped, and must wait until he receives assistance from above.

Side entrances might be more extensively used with advantage in pipe drainage, or, as they might be more strictly termed, shafts, for the purpose of inspection, flushing, &c. These shafts could be sunk below the level of the bottom of the pipe sewer, so as to form cesspits; on the lower side of the shafts nearest the outlet penstocks could be fixed, so that a head of water could be raised at each shaft, and the pipe sewer flushed as far as the next shaft, into the cesspit, at which point, when sufficient head was obtained, the penstock could be raised, the next length flushed, and so on to the outlet.

Junctions.—The junction of branch sewers with the main sewer should be made on a regular curved line, with a radius not less than 30 feet. The level of the invert of the branch sewer should be above that of the main sewer, such difference of level should be equal to the difference of height of their respective inverts, or in other words, the arches should spring from the same level. It is recommended by Mr. Rawlinson that the fall of

* Continued from page 288.

curved junctions should be increased, to compensate for friction; where sufficient fall can be obtained such increased gradient will no doubt be advantageous. Bell-mouthed junctions should be provided with ventilators and cesspits, to allow the foul gases to pass off at the highest point where they mostly accumulate.

House Drains.—House drains should in every case be formed of glazed stoneware pipes; they should be well laid to a regular gradient on a sound foundation of the maiden ground, or of concrete, so that no settlement might take place, and thereby cause deposit, and ultimately stoppage. Drainage should not be taken through the houses under the floors if it can by any means be avoided. Water-closets should be placed next external walls, so that they may be drained as direct as possible. Sinks should be connected with the drain of the watercloset, so as to flush it with the house washings, also the overflow from the waste of the cisterns.

A six-inch glazed drain pipe, with a proper fall, will be sufficient for the entire drainage of an eight-roomed house, and four-inch pipes for the sink and rain-water. Drain pipes should be connected with the sewer on a curved line, and the drain mouths should be provided with galvanized iron shackle-flaps, to prevent smell or flood-waters from rising up the house drains. All drains should be trapped by means of a syphon bend, or other suitable arrangement, at a point easy of access in case of stoppage; also, all inlets for surface drainage of yards, areas, &c., should have cesspits, with syphon over-flows, as one of the surest means of preventing deposit in drains is to check the admission of sand and other matter at these points.

Regulation and supervision of Buildings.

The regulation and supervision of buildings, both in the metropolis and in provincial towns, is extremely limited: and if we would check the present abuses in the construction of modern buildings, and also the defective sanitary arrangements, whereby the lives of the public are endangered, we must considerably augment the powers contained in the several Acts of Parliament now in force.

In the metropolis, we have the Metropolitan Building Act, 1855, 18 and 19 Vict., c. 122; the Metropolis Local Management Act, 18 and 19 Vict., c. 120; and the three Amending Acts—the 19 and 20 Vict., c. 112; the 21 and 22 Vict., c. 104; and the 25 and 26 Vict., c. 102. Also, the Nuisances Removal Act for England, 18 and 19 Vict., c. 121; amended by the 23 and 24 Vict., c. 77. In provincial towns powers are given to the municipal corporations, or other local authorities, to adopt the Public Health Act, 11 and 12 Vict., c. 63; and the Local Government Act, 21 and 22 Vict., c. 98. These several Acts have, generally speaking, fully answered the purposes for which they were designed, but they are now inadequate to meet the increasing demands for sanitary improvements and improved scientific construction.

The following statement will give some idea of the omissions in the Acts before mentioned, and will show the necessity for a full consideration of the subject, with a view to future legislation.

The Metropolitan Building Act.—This Act was specially framed for the prevention of fire, for which purpose its provisions are effectual; but with regard to the stability of buildings it is extremely deficient. It provides for the thickness of walls, but it contains nothing whatever in reference to the strength of the timbers, iron girders, columns, fireproof floors, roofs, &c., so that a house may be built in London with its timbers of any scantling, and the district surveyor is powerless to act. Let anyone take a walk in the suburbs and, examine the new buildings which are springing up like mushrooms, and he will perhaps be astonished that they hold together so well as they do. He will see the lintels sagging under the weight of the brickwork above, and yet they will have to sustain the moving load on the floors; he will see the uprights of the partitions and the thin story posts to the shops bending with the weight already put upon them; also the joists deficient in depth, wide apart, and incapable of bearing the weight of one man without considerable deflection; gutter-plates of from 12 to 15 feet span, so light in construction that the previous fall is not equal to the permanent set, thereby causing the rain-water to lie in the centre, and many other evils resulting from insufficient timbering.

In the construction of warehouses, hotels, and many other large buildings, iron now plays a most important part, and yet there is no guarantee as to the proper distribution of the metal beyond that which is given by the known professional standing of the architect, engineer, or builder. That such supervision is insufficient becomes too evident when we have such a long list of accidents resulting from an imperfect knowledge of construction. The floors of warehouses which may have to sustain great weights should be expressly designed for the particular goods with which they are to be stored, and should have a cast-iron plate fixed to the wall, in a conspicuous position, stating the total load which the floor is calculated safely to sustain, certified by some competent and responsible authority appointed for such duty.

The necessity of some such arrangement is exemplified in the case of a warehouse which is designed for light goods, and is afterwards let out in floors for any other purpose, when, perhaps, one of the upper floors is taken by an ironfounder or machinist, or other person requiring to store heavy goods, and he naturally makes the most of the space, and crowds in as much material as he can, to the danger of the life of the occupier below, who has no remedy, but must either chance the floor bearing the load, or vacate the premises.

Again, with reference to iron columns: they are mostly used in shop fronts of the smallest possible section, so that they may impede as little light as possible, and in some instances they have to support a heavy mass of brickwork for three or four stories, as well as half the weight of the floors of the front rooms, and the moving load thereon. It is admitted that cast-iron in compression will sustain a great weight, but still it is an uncertain material, and a good margin should be allowed in case of great vibration of the floor above, sudden blows, and other causes of damage to which it is exposed in such a position.

In the present desire to prevent the spread of fire by erecting fireproof floors, we are very likely to incur other dangers from the insufficient strength of the various kinds of patent flooring now in use, which the inventors, in order to render as cheap as possible, have reduced to the minimum amount of material. This evil is further increased by the too common practice of using the same depth of iron joist for different spans, so as to preserve an uniform height of story throughout. This is clearly an erroneous principle, as you must have in the floors of some of the rooms either a waste of metal or insufficient strength. Fireproof floors, formed of brick arches springing from iron girders, are in many cases constructed with a very small sectional area of tie rod to retain the thrust against the external walls, and in a few cases the ties have been omitted altogether.

The roofs of modern public buildings, more especially those of iron, leave little to be desired in their construction; indeed, they appear to have fallen into the hands of men who are masters of the principles by which the proper sectional area of each member is fairly apportioned; but still there are isolated instances in which roofs of large span have been designed by the rule of thumb, in which the tie beams sag with their own weight, and in which the trussing is so erroneous in principle that they are insecure in a strong wind. Roofs of theatres are mostly designed so as to utilise some portion of their area for carpenters' or scene-painters' shops or stores: when this is done they should be constructed *entirely* of fireproof material, so that if a fire should break out it might be prevented from spreading to other portions of the building. The same rule would apply to the galleries, and, indeed, to every portion of the building except the fittings.

Fireproof material, in like manner, should also be used in music halls, concert-rooms, hotels, and every building in which a number of persons are congregated together. In the Metropolitan Building Act, 18 and 19 Vict., c. 122, s. 30, it is stipulated that every public building shall be constructed in such manner as may be approved by the district surveyor; but this is very indefinite, as it is not clearly stated to what extent the jurisdiction of the district surveyor shall apply. It was evidently intended to cover the weak points of the act, which the framers shirked; but, as is always the case with any rule or restriction of a loose character, it is subject to a very wide and liberal construction. The surveyor does not feel himself justified in calling upon the designers of public buildings to remodel their plans, or to pull down and reconstruct portions of the works which do not come up to his standard of safety, or to his interpretation of the intention of the act; consequently, if the buildings are constructed in a generally substantial manner, they are allowed to pass.

Section 22 of the Building Act provides that all staircases, landings, lobbies, &c. in public buildings shall be built of fireproof material, but there is no provision, excepting that in sec. 30, before mentioned, for the proper construction of the passages and doorways, so that sufficient egress is readily and directly obtained in case of fire or accident. The height of the doorways for egress from public places of amusement should not be less than 7 feet, and their collected widths should bear a fixed stipulated proportion to the number of persons which the building is estimated to contain. The doors should be hung on swing pivot hinges, so that they would open easily from either side. The want of this arrangement was sadly felt in the deplorable accident at the music hall, Surrey-gardens.

Now let us turn to another branch of the subject of a somewhat different character, but equally deserving of consideration, viz., the foundations of buildings. In the schedule of the Building Act it is stipulated that the foundations shall rest on the solid ground, or upon concrete, or upon other solid substructure; but what is the effect of this clause in practice? Does it bind the builder to erect his building on the best foundation, natural or artificial, he can obtain? Certainly not; it merely binds him to build on the maiden earth, be it what it may; so that we see houses erected every day upon the mould, loam, clay, or other soil that may happen to exist in the locality.

Another evil of modern house-building is the practice of constructing the ground-floors without suitable space underneath for ventilation, therefore it is a common practice to find the ground joists rotten after a few years; or else Paterfamilias discovers that the lower story is so damp from the use of place brick foundations, the absence of concrete or damp-proof course, that it is practically uninhabitable. If he asks why the district surveyor allows this, he is told the act does not apply, it is framed chiefly to prevent the spread of fire: as regards the health or life of the occupier that is left to providence. It surely would not be considered a hardship if builders were compelled to excavate the entire area, so as to keep the ground-floor joists at least one foot above the ground in every part, and that such space should be connected with the external air by iron grating or otherwise.

The Building Act in its present form fully answers its purpose in imposing necessary restrictions in the construction of buildings, so as to prevent fire, but it requires considerable extension in its provisions in order to give the district surveyors power to exercise some control over the scamping propensities of modern builders. The present mode of supervision by district surveyors is as faulty as the regulations of the Act. It is an absurdity that the district surveyor should be paid by the builder over whom he is supposed to exercise restrictive powers. It is admitted that district surveyors are as a rule gentlemen of the highest integrity and honour, but it is placing them in a false position to allow them to receive money from men with whom they should be perfectly independent. The system of payment by fees is open to many objections. In the suburban districts the surveyor is in receipt of a large income, and in the central districts he does not receive sufficient to pay his office expenses; yet he is expected to exercise the same vigilance, in keeping a sharp look-out that buildings are not erected, or alterations made, without the builder giving proper notice. In a district where there is a considerable amount of building the amount of supervision is quite inadequate. It is simply impossible for any surveyor to efficiently supervise the erection of 500 houses in one year, and attend to a large private practice as well, with the assistance at present engaged. It is an old maxim that no man can serve two masters. A district surveyor should be perfectly free from all local influence, therefore he should not be allowed private practice, but should be paid by the Metropolitan Board of Works a salary in proportion to the extent of the duties of the district, out of a common fund raised by the fees received from builders.* Clerks of works or assistant surveyors should also be appointed to each district, so as to insure an effectual supervision. The public would then have less cause to complain of the imperfections of modern buildings, and would also have a balance in hand for local improvements.

Metropolis Local Management Acts.—In the Metropolis Local Management Act, and Amended Acts, we have several useful restrictions as to buildings. In the 18 and 19 Vict., c 120, s. 143, and the 25 and 26 Vict., c. 102, s. 75, it is provided, that no building shall be erected beyond general line without consent of the Metropolitan Board of Works; but this is generally interpreted to mean that the building shall not be erected before the line of frontage of the adjoining houses or the houses nearest thereto; it does not oblige the owner to set back so as to preserve an uniform width of street, although the Metropolitan Board have powers (s. 74) to cause buildings *projecting* beyond the line of street, when pulled down or demolished from any cause, to be set back to such a line, and in such a manner, for the improvement of any street, as they shall direct, provided that the Board shall compensate the owner for any loss he may sustain. Under this clause many improvements might be carried out, at a small cost, but the proper moment is allowed to slip by, and at a future day the expense will be considerably increased. As an instance thereof, the narrow portion of the Strand, next the Church of St. Mary-le-Strand, lately occupied by Sam's Hotel, might have been widened, Holywell-street abolished, and a new frontage formed next the Strand, with a good roadway north of the church. As it is, the hotel is being rebuilt on the old site, when of course the opportunity for improvement is lost. The Provincial Bank, Charing-cross, may also be mentioned as an example of a costly building having been allowed to be rebuilt in a narrow portion of the roadway, which will, eventually, require to be set back to the same width as at Whitehall. Likewise, the Inns of Court Hotel has been built in that portion of Holborn which should be widened, to preserve anything approaching to uniformity in the width of the street. To do the Corporation of London justice, it must be confessed, in this respect, they have set the Metropolitan Board an example they would do well to follow. In many parts of the City we see small improvements going on by setting back buildings when rebuilt; in fact, no opportunity is lost to effect this desirable object.

In case of the erection of any building without the consent of the Metropolitan Board, or contrary to the terms upon which such erection may have been granted, it shall be lawful for the vestry of the parish, or the board of works for the district in which such building is situate, to cause to be made a complaint thereof before a justice of the peace, who shall thereupon issue a summons requiring the owner, occupier, or builder to appear to answer such complaint, which, if proved, the owner, occupier, or builder to demolish such building and pay costs of hearing, and in default of such demolition by builder, &c. the duty to devolve upon the vestry, with power to recover costs. But, supposing the vestry or district board consent to the erection of such building, and the Metropolitan Board dissent, and order the building to be demolished, they are powerless to act: therefore, without consent of district board, this clause is inoperative. Several cases of this kind have occurred, and the buildings objected to by the Metropolitan Board are standing to this day.

Under the 25 and 26 Vict., c. 102, s. 85, regulations as to height of buildings are in force, so that no building can be erected in any *new* street of a less width than 50 feet, which shall exceed in height the width of street, without consent of the Metropolitan Board of Works. But why stop at 50 feet, and why give the board the option: if it is an advisable restriction, of which there can be no question, why not make it compulsory to all new streets? Garrick-street in this respect is not a very favourable illustration of the present enactment. In this act we have regulations as to the occupation of underground rooms as dwellings (s. 103, in which it is ordered that the room shall be 7 feet in height, and that one foot of its height shall be above the footway of the street.) It is a question worthy of consideration, if it is desirable that such rooms should be occupied as a separate dwelling when we have no adequate provisions against over-crowding, and no means of enforcing ventilation: at least *half* the height of such rooms should be above the footway of the street.

District surveyors are, under the 25 & 26 Vict., c. 102, s. 62, required to report without fee or reward in the months of June and December in each year, and at all other times when they shall be required to do so by the vestry or district board, all underground rooms occupied as dwellings. This is a great hardship upon the surveyors, and exceedingly inconsistent that any officer should be expected to perform duties of an onerous and responsible nature without proper remuneration. The drainage of buildings is well provided for, requiring that all such works be executed to the satisfaction of the surveyor of the board or vestry; and in default of the owner providing requisite drainage, water-closets, ashpits, &c., the board have power to execute the same, and recover from the owner. The question of over-crowding is one of the chief blots upon our municipal legislation: we have no legal means of getting rid of this monstrous evil, excepting by the powers contained in the Nuisance Removal Act, 18 & 19 Vict. c. 121, s. 29, under which, by the certificate of the medical officer,

* Proposed by Mr. Robert Taylor.

the local authority can institute proceedings to abate such overcrowding. It would be a much more effectual arrangement if the number of occupants were limited to the cubic contents of the rooms, any evasion thereof being visited with a fine upon the occupier or owner of £5. and a further fine for each and every day such infringement is carried on by allowing such room or rooms to be so occupied.

Public Health Act, 1848, *and Local Government Act*, 1858.—The powers vested in the local authorities adopting these acts are much more comprehensive than those in the metropolis, as by the 21 & 22 Vict., c. 98, s. 34, every local board may make bye-laws with respect to the new streets, the structure of walls of buildings, sufficiency of space adjoining thereto, ventilation and drainage; as regards the structure of walls, the local boards in some towns are rather lax, as we find party walls erected only half-brick thick, and the roofs connected right through without any party wall whatever, so that if a fire takes place the whole row of houses must perish. The structural defects as to timbers, &c., are the same as before-mentioned as existing in the metropolis, which the local boards require fresh powers to amend. In some towns ventilation is made compulsory, and the owners of new houses are not allowed to let unless they receive a certificate from the surveyor that the houses are fit for habitation. This very useful and necessary restriction might with advantage be adopted throughout the kingdom, more especially in the metropolis, where we have so many wretchedly built and ill-ventilated buildings. It is somewhat difficult to impose regulations as to the construction of buildings which unscrupulous speculating builders will not find means to avoid. The best remedy against the evils of modern building rests with the public themselves; whilst there is a demand for *cheap* houses there will necessarily be a supply. Let the modern architect show that he can build a good house at a fair price, and perhaps the public will see the utility of employing him; and before they purchase a house let them take care to have it examined by a competent surveyor. Also when Paterfamilias wishes to hire a house, let him take some precautions to ascertain who is the builder.

PROGRESS OF GUN COTTON MANUFACTURE.*

By Mr. Prentice.

Gun cotton, called by Liebig "the explosive of the future," has lately become a matter of great interest, engaging the attention of scientific men in this and other countries, has formed the subject of popular lectures, and has already been brought into practical use by many of our hard-working miners and quarry men. This is mainly to be attributed to the striking manner in which the subject of Austrian gun cotton, prepared by the process of Baron Lenk, was introduced at the Newcastle meeting of this Association two years since, when in the chemical section Dr. Miller, Dr. Gladstone, and Professor Abel, and Mr. Scott Russell in the mechanical section, so ably called attention to the detail of its manufacture, and gave accounts of its mighty energy. This is only another instance in which the British Association proves its utility in assisting to develope practical results from scientific investigations. During the past twelve months considerable advance has been made in the application of gun cotton as an explosive material. Reports from various mining works indicate a steady progress towards the general use. At first it seemed probable that gun cotton would be effectively and economically employed only in hard rock, such as granite. Doubtless in such material its full power was most easily developed. Experience showed, in working amongst soft rocks and coals, that the form in which gun cotton had been prepared was not the best for obtaining satisfactory and economical results. The charge was confined in a small space, and acting on a short length of the hole or drill showed immense force, but expended a considerable portion of it in enlarging the base of the hole, while the remainder had only the effect of splitting the lock, instead of throwing over the burden. The mechanical application to which gun cotton seems so ready to submit was consequently varied. By the introduction of a core of wood, the charge of cotton was made to occupy double the length of hole, the wood filling the internal space of the charge, so that in the explosion a much larger surface was acted upon, while the gases were well confined. In this manner work is now executed in coal and in slate, obtaining even in soft material the full force which was at first claimed for gun cotton in hard rock only, namely, six times that of an equal weight of gunpowder. Comparative trials have clearly demonstrated the superior power and advantages of gun cotton. In Wales, driving through the "hard" overlying the slate vein, one of the contractors reports that his level or tunnel could be advanced 9½ yards when the men worked with gun cotton, while 8 yards was the most accomplished in the same space of time when gunpowder was used. This point deserves the fullest consideration, for although gun cotton, used in holes as ordinarily prepared for powder, is found to answer satisfactorily, there is no doubt that when judgment is exercised, and the work put before the holes is proportionate to the enormous power of the charge, a given distance will be advanced with a less number of holes, with consequently a further considerable reduction in the cost. In close under-ground work the fullest advantages are still more manifest. There is no smoke, neither are there those deleterious product which cause the use of gunpowder to be so noxious and injurious.

In 1864, the Commissioners appointed to inquire into the condition of mines in Great Britain rendered their report to both Houses of Parliament. In reference to the air in mines, and the sanitary effects of gun cotton and gunpowder respectively, Dr. Angus Smith, F.R.S., reports:—"As gunpowder is evidently one of the most deleterious ingredients affecting the air of mines, the commission was desirous that the products of combustion of gun cotton should be examined, in order to find if that substance promised to perform the work of blasting with a less injurious influence on the air; for if gun cotton could be used of a kind which gives out none of the oxides of nitrogen, an advantage of the most pleasing kind would be gained. The solid matter, the crystals and carbon, would cease to trouble the miner, as well as the sulphur compounds that follow every explosion. To examine this, Lord Kinnaird had arranged a meeting of captains of mines at Dolcoath, Camborne, with whom I was to act, examining the products of combustion. Accident prevented me going down the mine, but Mr. Richard Pearce, of the Royal Institution, Truro, took the apparatus down, passed the air through the solutions, and brought up specimens immediately after the explosions. Several solutions were examined, the amount of air passed through being 1470 cubic inches, but only a trace of oxides of nitrogen could be found in any, and with difficulty. Considering that nitrates could be found in a few cubic inches of air after the explosion of gunpowder, the result must be considered excellent. Whilst the experiments were going on underground, I selected a hut somewhat about the height and breadth of a 'close end,' and about 10 feet long, as fitted for making similar trials above ground. In this was laid a large mass of granite; a hole was bored in it by a miner, and it was fired with gun cotton. The explosion was pronounced successful, but although it was believed by the miners present that the gun cotton had done all to the stone that powder could possibly have done, they were surprised that the roof of the hut was not blown away. They held this as a proof that the action of the cotton was different from that of the powder. Probably the vapour of water condensed before reaching the roof. We all entered the hut instantly. The place was full of a light coloured or nearly white vapour, with a rather pungent smell, having in it nothing at all resembling nitrous gas, or indeed any acid substance whatever. I could think of nothing similar to this containing nitrogen. After all there was not much of it, and it was far from resembling in intensity the smell of gunpowder after explosion in such a place. If the senses could have detected any nitrous gases in the vapour, I would not speak in favour of it, but after remaining in the midst of it till it disappeared I am compelled to defend it against any such charge. The man who bored was very much pleased, and all the workmen with whom I spoke preferred very much the vapour of gun cotton to that of gunpowder. There was now a new riddle. Why was there smoke, and what was the smell observed? No one seemed to know the smell of a fuse; it is never used by itself, and although sometimes it burns without lighting the charge, the men do not enter such places till the smoke is gone. In order to settle the point, the hut was shut up, a burning fuse being enclosed in it. When we entered it after two minutes, there was the same white smoke and the same smell before described; it was now explained to be that of distilled or half-burnt canvas and tar mixed with the gunpowder of a fuse. So strong was it, that I do not hesitate to say that the smell of the gun cotton was not in the slightest degree perceptible;

* Read before the British Association.

in other words, it had no perceptible influence on the smell in the hut. Such a fuse is not necessary. It is not used everywhere, and in reality seems rather to be a peculiarity of some districts; those manufactured in Camborne for most places being different in composition. In every trial in which the effect on the senses or the breathing, and as far as we can judge on health, was considered, gun cotton has come off with the highest character. I feel much confidence in speaking thus highly in its favour."

Considerable interest in this subject has been excited in foreign countries, as well as in distant British colonies, in some of which the use of gun cotton manufactured in this country is established. With reference to the manufacture two things call for special remark. First, as to the stability of the material. To satisfy ourselves of this we submitted it to Mr. Hadow, of King's College, and the following was his report:—"Gentlemen, I have carefully examined the sample of gun cotton rope, supplied as a sample of your manufacture, and am able to report favourably upon it. The gun cotton proves on analysis to be the highest and most powerful explosive of the series of substitution compounds formed by the action of nitric acid on cotton. It contains the maximum amount of peroxide of nitrogen, corresponding with the formula C 36 (9 N—H 21 O 4) O 30. This was proved by submitting a portion, carefully dried in vacuo, to the reducing action of an alcoholic solution of the double sulphide of potassium and hydrogen, when it gave an amount of cotton almost exactly corresponding to that which calculation requires (100 parts gave 54 80, calculation requires 54 54 of cotton); and secondly, by treating another portion, likewise weighed after drying in vacuo, with a mixture of the strongest nitric and sulphuric acids for three hours, when the presence of any of the lower substitution compounds would have been detected by an increase of weight after washing and drying (the next lower substitution compound gaining 5·3, and the next lower 11·3 per cent. by such treatment). The sample, however, gained nothing in weight by the immersion; on the contrary, as experience has proved to be the case with gun cotton that has reached the highest stage of substitution, a loss was sustained of 0·95 per cent., which corresponds very closely with what experiment shows to be the loss sustained always through solution by immersion of the strongest gun cotton for three hours in the mixed acids. To determine its stability, it was placed in a tube with blue litmus paper, side by side with other samples, each contained in a separate tube furnished with litmus paper. These were then simultaneously submitted to the temperature of boiling water. Some of the samples showed immediate signs of decomposition by reddening the litmus paper, and in a short time filling the empty part of the tube with the red vapours of peroxide of nitrogen; while the sample you supplied showed no trace of decomposition until about forty minutes, before which time some of the more decomposable specimens had been exploded. From this result it may be concluded that your gun cotton possesses a high degree of stability, and of all the examples I have examined it is the least likely to change during prolonged storing. The sample was found perfectly free from all uncombined acids—it had, in fact, a very feeble alkaline reaction (due to silicate of soda), only discoverable by testing with care. Washed with water it loses about 3·08 per cent. in weight, the loss consisting of silica and silicate, and sulphate of lime, partly suspended, partly dissolved, together with traces of organic matter, evidently introduced, since the treatment with acids, as it is non-nitrated, and chars slightly on evaporation to dryness. The gun cotton after washing still retains about 1·64 per cent. of silica and sulphate of lime. In the preceding statement as to the amount of cotton obtainable from the gun cotton, and as to the weight after immersion in acids, the amount of ash and soluble matter was ascertained both before and after treatment, and was deducted in the calculations. In reply, then, to your questions, it may be stated that your sample consists of a definite chemical compound, the highest of the series; that it has been carefully prepared, being remarkably stable at 212°; and is quite free from uncombined acids."

The second thing calling for remark relates to the greater safety to the workpeople employed. The British Association was last year informed of the introduction of the wet process, by which the gun cotton was manipulated through all its stages in a damp or wet state. The suggestion that this plan should be adopted was made by Dr. Miller, when, with Dr. Frankland, Dr. Thomas Richardson, Professor Abel, and Mr. Scott Russell, he visited the manufactory, and inspected the operations. This has been extended even to the point of storing under water. The magazines at the factory now containing the stock of gun cotton ropes, cut up into mining charges, consist of tanks with tons of the material submerged in many more tons of distilled water. As orders are received charges are taken out of the water, and in a few hours are ready for packing and delivery. It being therefore unnecessary that any large quantity of explosive gun cotton should be kept on the works, great safety is attained, and the chance of any alarming accident is entirely removed. In the application of gun cotton to rifles and sporting guns considerable experience has been gained. The latest trials have been very successful, and indicate that we are arriving at the principles by which cannon cartridges also may be successfully prepared. From the scientific point of view there are no instantaneous forces generated either mechanically or chemically, and motion or any process of composition or decomposition can only take place by degrees; but from the practical point of view there are compounds which decompose with such immense velocity, which require such an extraordinary small space of time for their decomposition, that for all intents and purposes they may be considered instantaneous. Such compounds are called fulminating. Experiments with gun cotton show that it may be made, practically speaking, instantaneous in its decomposition. Using high densities (30—40 lb. per cubic foot) in an open condition, or in other words producing many channels through the dense mass of the compound, the destructive effect of such confined masses of gun cotton is, in every respect, similar to the strongest fulminates. It is well known that fulminating compounds cannot be used for propelling projectiles, on account of the destructive effects produced upon the guns. The whole point of the possibility of the application of gun cotton therefore turns upon the question, whether or not a certain quantity of gun cotton can be made to decompose in the given time require by a mass to move through a certain distance, when propelled by a force limited to the strength of the gun. It would lead too far to enter into the details of the trials, which have satisfactorily showed that the time of decomposition of a certain gun cotton charge may be increased considerably beyond the requirements of the artillerist—or the compound may be made too slow for purposes of artillery. It has been found that the gun cotton charge must be divided into at least two individually different parts, which, for the sake of clearness, may be called the exterior and the interior charge. The mechanical composition of both these is materially different; the exterior being a small fraction of the whole (from about one-sixth to one-third) in an open condition of low density (3 lb. to 10 lb. per cubic foot) in relation to the space in which it explodes. This generates the initial pressure required to start the shot from rest. The interior charge on the other hand, being sufficiently separated from the other by a strong resisting medium, and ignited at one or more ends by the explosion of the outer charge, contains the remaining quantity of gun cotton (5·6 to 2·3) under a high density (40 lb. to 80 lb.) The object of the interior or core charge is to generate the propelling gas during the motion of the projectile through the barrel of the gun, and to supply the gas at a rate corresponding to the accelerated motion of the projectile. The resisting medium which separates the outer and inner charge may be a cylindrical tube of considerable strength, and it has been found that the relative quantity and density of both charges —outer and inner—and the dimensions of the cylindrical tube, its inner diameter, length, and thickness, are quantities so intimately connected that the omission of or inattention to one of them wholly impairs the effect, uniformity, or powers of the gun cotton cartridge. Without going into actual figures, it may be stated that the initial velocity of the Enfield rifle projectile, with the use of such gun cotton cartridge, already exceeds the initial velocity of the service gunpowder charge. This has been tested. by means of trajectories due to gun cotton and gunpowder charges, each projectile recording its path of flight or trajectory The maximum incurvation of the trajectory of the service gunpowder charge of the Enfield rifle, within a hundred yards of the muzzle of the gun, being on the average 3⅜ in.—that of a series of gun cotton cartridge made on the above principle has been, on the average, 3⅛ in.; the gun cotton trajectory being therefore flatter by ¼ in. in the first hundred yards. The path of the projectile was recorded by means of screens, every 50 feet apart. These velocities have been obtained with a service Enfield rifle, out of which about two thousand gun cotton rounds have been fired, without any signs of distress upon the gun, as officially reported by the inspector of small arms at Woolwich.

The trials of gun cotton cartridges for rifles and ordnance being in a course of progress, it is for the present preferred not to give definite quantities respecting the construction of such cartridges. When the gun cotton charges shall have been finally settled by the Government committee, a full account of the trials will doubtless be given. The cartridges will give still better results when made with machinery better adapted to ensure uniformity of construction. The actual dimensions and quantities of gun cotton cartridges for fowling or sporting guns may be given, from which a general idea may be gained as to the construction of gun cotton cartridges. Breech-loading sporting gun, gauge No. 16, charges made up in cases, gun cotton charge: exterior, 4·3 grains gun cotton muslin; interior, 18 grains of solid 6-fold braid of fine yarn; density of core charge; 67 33 lb. per C. F. Dimensions of cylindrical tube containing core charge: lengths of tube, ·94 inch; inner diameter ·35 inch; outer diameter, ·5 inch. First wad, next the gun cotton cartridge, boiled in wax; second wad, soft as usual, 1 oz. of shot, ignition of core charge both ends. The shooting of this cartridge is superior to sporting gunpowder in every respect. One little incident from the sporting field is not without significance. The boy carrying the game bag made the following homely remark:—"This cotton business is likely to be a bad thing for the birds," as he found his wallet filling much more rapidly by the gun which was fired with the gun cotton than that charged with gunpowder. Such a remark would not excite surprise with any person who had seen the greater penetration, and the more equable distribution of the shot, as shown by the state of the targets after the competitive trial with each explosive.

ON THE ELASTICITY AND VISCOSITY OF METALS.*

By Prof. W. Thomson, LL.D., F.R.S., F.R.S.E.

Among the experimental exercises performed by students in the physical laboratory of the University of Glasgow, observations on the elasticity of metals have been continued during many years. Numerous questions of great interest, requiring more thorough and accurate investigation, have been suggested by these observations; and recently they have brought to light some very unexpected properties of metallic wires. The results stated in the present communication are, however, with one or two exceptions, due to the careful experimenting of Mr. Donald Macfarlane, official assistant to the Professor of Natural Philosophy, whose interested and skilful co-operation has been most valuable in almost everything I have been able to attempt in the way of experimental investigation.

The subject has naturally fallen into two divisions—viscosity and moduli of elasticity.

Viscosity.—By induction from a great variety of observed phenomena, we are compelled to conclude that no change of volume or of shape can be produced in any kind of matter without dissipation of energy. Even in dealing with the absolutely perfect elasticity of volume presented by every fluid, and possibly by some solids, as, for instance, homogeneous crystals, dissipation of energy is an inevitable result of every change of volume, because of the accompanying change of temperature, and consequent dissipation of heat by conduction or radiation. The same cause gives rise necessarily to some degree of dissipation in connection with every change of shape of an elastic solid. But estimates founded on a thermo-dynamic theory of elastic solids, which I have given elsewhere,† have sufficed to prove that the loss of energy due to this cause is small in comparison with the whole loss of energy which I have observed in many cases of vibration. I have also found, by vibrating a spring alternately in air of ordinary pressure, and in the exhausted receiver of an air pump, that there is an internal resistance to its motions immensely greater than the resistance of the air. The same conclusion is to be drawn from the observation made by Kupffer in his great work on the elasticity of metals, that his vibrating springs subsided much more rapidly in their vibrations than rigid pendulums supported on knife edges. The subsidence of vibrations is probably more rapid in glass than in some of the most elastic metals, as copper, iron, silver, aluminium‡; but it is much more rapid than in glass, marvellously rapid indeed, in some metals (as, for instance, zinc),* and in india-rubber, and even in homogeneous jellies.

* From the Proceedings of the Royal Society.

† On the Thermo-elastic Properties of Solids, "Quarterly Journal of Mathematics," April, 1857.

‡ We have no evidence that the precious metals are more elastic than copper, iron, or brass. One of the new bronze pennies gives quite as clear a ring as a silver, two-shilling piece tested in the usual manner.

The frictional resistance against change of shape must in every solid be infinitely small when the change of shape is made at an infinitely slow rate, since, if it were finite for an infinitely slow change of shape, there would be infinite, which we may be sure does not exist in nature.† Hence there is in elastic solids a molecular friction, which may be properly called viscosity of solids, because, as being an internal resistance to change of shape depending on the rapidity of the change, it must be classed with fluid molecular friction, which by general consent is called viscosity of fluids. But, at the same time, it ought to be remarked that the word viscosity, as used hitherto by the best writers, when solids or heterogeneous semi-solid semi-fluid masses are referred to, has not been distinctly applied to molecular friction, especially not to the molecular friction of a highly elastic solid within its limits of high elasticity, but has rather been employed to designate a property of slow continual yielding through very great, or altogether unlimited extent of change of shape, under the action of continued stress. It is in this sense that Forbes, for instance, has used the word in stating that "Viscous Theory of Glacial Motion," which he demonstrated by his grand observations on glaciers. As, however, he, and many other writers after him, have used the words plasticity and plastic, both with reference to homogeneous solids (such as wax or pitch, even though also brittle, soft metals, &c.), and to heterogeneous semi-solid semi-fluid masses (as mud, moist earth, mortar, glacial ice, &c.), to designate the property‡ common to all those cases of experiencing, under continued stress, either quite continued and unlimited change of shape, or gradually very great change at a diminishing (asymptotic) rate through infinite time, and as the use of the term plasticity implies no more than does viscosity, any physical theory or explanation of the property, the word viscosity is without inconvenience left available for the definition I propose.

To investigate the viscosity of metals, I have in the first place taken them in the form of round wires, and have chosen torsional vibrations, after the manner of Coulomb, for observation, as being much the easiest way to arrive at definite results. In every case one end of the wire was attached to a rigid vibrator with sufficient firmness (thorough and smooth soldering I find to be always the best plan when the wire is thick enough); and the other to a fixed rigid body, from which the wire hangs, bearing the vibrator at its lower end. I arranged sets of observations to be made for the separate comparisons of the following classes:—

(*a*) The same wire with different vibrators of equal weights (to give equal stretching-tractions), but different moments of inertia (to test the relation between viscous resistances against motions with different velocities through the same range and under the same stress.)

(*b*) The same wire with different vibrators of equal moments of inertia but unequal weights (to test the effect of different longitudinal tractions on the viscous resistance to torsion under circumstances similar in all other respects.)

(*c*) The same wire and the same vibrator, but different initial ranges in successive experiments (to test an effect unexpectedly discovered, by which the subsidence of vibrations from any amplitude takes place at very different rates according to the immediately previous molecular condition, whether of quiescence or of recurring change of shape through a wider range.)

(*d*) Two equal and similar wires, with equal and similar vibrators, one of them kept as continually as possible in a state of vibration from day to day, the other kept at rest, except when vibrated in an experiment once a day (to test the effect of continued vibration on the viscosity of a metal.)

Results.

(*a*) It was found that the loss of energy in a vibration through one range was greater the greater the velocity (within the limits

* Torsional vibrations of a weight hung on a zinc wire subside so rapidly, that it has been found scarcely possible to count more than twenty of them in one case experimented on.

† Those who believe in the existence of indivisible, infinitely strong and infinitely rigid very small bodies (finite atoms!) may deny this.

‡ Some confusion of ideas on the part of writers who have professedly objected to Forbes' theory while really objecting only (and I believe groundlessly) to his usage of the word viscosity, might have been avoided if they had paused to consider that no one physical explanation can hold for those several cases, and that Forbes' theory is merely the proof by observation that glaciers have the property that mud (heterogeneous), mortar (heterogeneous) pitch (homogeneous), water (homogeneous), all have of changing shape indefinitely and continuously under the action of continued stress.

of the experiments); but the difference between the losses at low and high speeds was much less than it would have been had the resistance been, as Stokes has proved it to be in fluid friction, approximately as the rapidity of the change of shape. The irregularities in the results of the experiments which up to this time I have made, seem to prove that much smaller vibrations (producing less absolute amounts of distortion in the parts of the wires most stressed) must be observed before any simple law of relation between molecular friction and velocity can be discovered.

(b) When the weight was increased the viscosity was always at first much increased; but then day after day it gradually diminished, and became as small in amount as it had been with the lighter weight. It has not yet been practicable to continue the experiments long enough in any case to find the limit to this variation.

(c) The vibration subsided in aluminium wires much more rapidly from amplitude 20 to amplitude 10, when the initial amplitude was 40, than when it was 20. Thus, with a certain aluminium wire and vibrator No. 1 (time of vibration one way 1·757 second), in three trials the numbers of vibrations counted were:

	Vibrations.		
Subsidence from 40 initial amplitude to 20 ...	56	64	64
And from 20 (in course of the same experiments) to 10 ...	96	98	96

The same wire and same vibrator showed—

Subsidence from 20 initial amplitude to 10 (average of four trials) ... 112 vibrations.

Again the same wire with vibrator No. 2* (time of vibration one way 1·236), showed in two trials—

	Vibrations.	
Subsidence from 40 initial amplitude to 20 ...	54	52
And continued from 20 to 10 ...	90	90

Again, same wire and vibrator—

From initial amplitude 20 to 10, 103 vibrations (mean of eight trials.)

This remarkable result suggested the question *d*.

(d) Only one comparison was made. It showed in a wire which was kept vibrating nearly all day, from day to day, after several days, very much more molecular friction than in another kept quiescent except during each experiment. Thus two equal and similar pieces of wire were put up about the 26th of April, hanging with equal and similar lead weights, the tops and bottoms of the two wires being similarly fixed by soldering. No. 2 was more frequently vibrated than No. 1 for a few days at first, but no comparison of viscosities was made till May 15. Then—

No. 1 subsided from 20 initial range to 10 in 97 vibrations.
No. 2 the same subsidence in 77 vibrations.

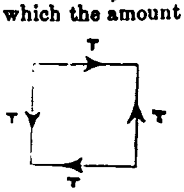
During the greater part of May 16 and 17, No. 2 was kept vibrating, and No. 1 quiescent, and late on May 17 experiments with the following results were made:—

		Time per vibration.
No. 1 subsided from 20 to 10 after 99 vibrations in 237 seconds ...		2·4
„ „ „ 98 „ 235 „ ...		2·4
„ „ „ 98 „ 235 „ ...		2·4
No 2 subsided from 20 to 10 after 58 „ 142 „ ...		2·45
„ „ „ 60 „ 147 „ ...		2·45
„ „ „ 57 „ 139 „ ...		2·45
„ „ „ 60 „ 147 „ ..		2·45

[Addition May 27, since the reading of the paper.]—No. 1 has been kept at rest from May 17, while No. 2 has been kept oscillating more or less every day till yesterday, May 26, when both were oscillated, with the following results:—

	Time per vibration.
No. 1 subsided from 20 to 10 after 100 vibrations in 242 seconds	2·42
No. 2 „ 44 or 45 vibrations... ...	2·495

Moduli of Elasticity.—A modulus of elasticity is the number by which the amount of any specified stress, or component of a stress, must be divided to find the strain, or any stated component of the strain, which it produces. Thus the cubic compressibility of water being $\frac{1}{21000}$ per atmosphere, its "modulus of compressibility," or its "volume modulus of elasticity," is 21000 atmospheres or $76 \times 13{\cdot}596 \times 21000 = 21{\cdot}7 \times 10^6$ grammes weight per square centimetre (as 13·596 is the density or specific gravity† of mercury, and 76 centimetres the height of the barometric column corresponding to the pressure defined as "one atmosphere"). Or again, Young's "modulus," which has generally been called simply the modulus of elasticity of a solid, is the longitudinal traction of a stretched rod or wire of the substance, divided by the extension produced by it. Or, lastly, the "modulus of rigidity" or, as it is conveniently called, simply "the rigidity" of an isotropic solid, is the amount of tangential stress divided by the deformation it produces—the former being measured in units of force per unit of area applied, as shown in the diagram, to each of four faces of a cube, and the latter by the variation of each of the four right angles, reckoned in circular measure.



Measurements of Young's modulus have been made for many bodies by many experimenters; but hitherto there have been very few determinations of rigidity, notwithstanding the great ease with which this can be done for wires by Coulomb's method. Accordingly, although several accurate determinations of Young's modulus have been made upon wires of different substances hung in the college tower of the University of Glasgow (which, by giving 80 feet of clear protected vertical space, affords great facilities for the investigation), I shall in this paper only refer to some of the results as bearing on the question, How are moduli of elasticity affected in one substance by permanent changes in its molecular condition?—which was my starting-point for all I have attempted to do experimentally regarding the elasticity of solids.

To determine rigidities by torsional vibrations, taking advantage of an obvious but most valuable suggestion made to me by Dr. Joule, I used as vibrator in each case a thin cylinder of sheet brass, turned true outside and inside (of which the radius of gyration must be, to a very close degree of approximation, the arithmetical mean of the radii of the outer and inner cylindrical surfaces), supported by a thin flat rectangular bar, of which the square of the radius of gyration is one-third of the square of the distance from the centre to the corners. The wire to be tested passed perpendicularly through a hole in the middle of the bar, and was there firmly soldered. The cylinder was tied to the horizontal bar by light silk threads, so as to hang with its axis vertical.

The following particulars show the dimensions of the vibrators of this kind which I have used:—

Cylinders.	Outer diameter.	Inner diameter.	Mean radius.	Weight in grammes.	Moment of inertia round axis in gramme-centimetres.
No. 1	15·3 centimes.	14·8 centimes.	7·525	527·92	29894
„ 2	15·3 „	14·8 „	7·525	523·45	29641
„ 3	10·295 „	9·79 „	5·021	360·54	9089
„ 4	10·3 „	9·81 „	5·027	726·40	18357
„ 5	10·25 „	9·745 „	4·999	718·36	17952
„ 6	10·295 „	9·805 „	5·025	342·45	8647

	Length.	Breadth.	Weight.	Moment of inertia round axis through middle, perpendicular to length and breadth.
Bar 1	24·03 centimes	·965 centimes	38·955 grms.	1877·5
„ 2	24·11 „	·95 „	46·68 „	2255·5

Towards carrying out the chief object of the investigation, each

* Of same weight as No 1, but different moment of inertia.

† The one great advantage of the French metrical system is that the mass of the unit volume (1 centimetre) of water at its temperature of maximum density (3°945 cent.) is unity (1 gramme) to a sufficient degree of approximation for almost all practical purposes. Thus, according to this system, the density of a body and its specific gravity mean one and the same thing; whereas on the British no-system the density is expressed by a number found by multiplying the specific gravity by one number or another, according to the choice (of a cubic inch, cubic foot, cubic yard, or cubic mile) that is made for the unit of volume, and the weight of a grain, scruple, gun-maker's drachm, apothecary's drachm, ounce troy, ounce avoirdupois, pound troy, pound avoirdupois, stone (imperial, Ayrshire, Lanarkshire, Dumbartonshire), stone for hay, stone for corn, quarter (of a hundredweight), quarter (of corn), hundredweight, or ton, that is chosen for unit of force. It is a remarkable phenomenon, belonging rather to moral and social than to physical science, that a people tending naturally to be regulated by common sense should voluntarily condemn themselves, as the British have so long done, to unnecessary hard labour in every action of common business or scientific work related to measurement, from which all the other nations of Europe have emancipated themselves. I have been informed, through the kindness of Professor W. H. Miller, of Cambridge, that he concludes, from a very trustworthy comparison of standards by Kupffer, of St. Petersburg, that the weight of a cubic decimetre of water at temperature of maximum density is 1000·018 grammes.

wire, after having been suspended and stretched with just force enough to make it as nearly straight as was necessary for accuracy, was vibrated. Then it was stretched by hand (applied to the cross bar soldered to its lower end) and vibrated again, stretched again and vibrated again, and so till it broke. The results, as shown in the following table, were most surprising:—

Length of wire in centimetres, l.	Volume, in cubic centimetres, V.	Density.	Moment of inertia of vibrator, Wk^2.	Time of vibration one way (or half-period), in seconds. T.	Rigidity in grammes weight per square centimetre. $\frac{2\pi^2 l^3 Wk^2}{g T^2 V^2}$	Substance.
60·3	1·1845	2·764	31771	1·14	241 × 10^6	Alumnm.
304·9	2·351	7 105	31896	4·31	359·6 10^6	Zinc[2].
237·7				4·76	410·3 10^6	Brass.
248·3				5·456	354·8 10^6	,,
261·9	1·703	8·398		5·96	350·1 10^6	,,
2435·0	15·30	8·91	38186	16·375	448·7 10^6	Copper.
,,	,,	,,	61412	20·77	448·4 10^6	,,
214·4	1·348	8·864	31771	5·015	433·0 10^6	Copper[3].
,,	,,	,,	61412	6·982	431·8 10^6	,,
143·7	·9096	8·674		3·381	393·4 10^6	Copper[4]
286·8			20612	4·245	442·9 10^6	Copper.[5]
291			,,	4·375	435·6 10^6	,,
293			,,	4·417	436·2 10^6	,,
296·1			,,	4·500	433·8 10^6	,,
300·0			,,	4·588	434·0 10^6	,,
303·4			,,	4·646	437·8 10^6	,,
309·3			,,	4·833	428·6 10^6	,,
313·2			,,	4·931	427·5 10^6	,,
317·4	1·962	8·835	,,	5·040	425·9 10^6	,,
215·6			31771	8·155	442·3 10^6	Copper.[6]
235·5			,,	9·425	432·2 10^6	,,
251·9	·827	8·872	,,	10·463	428·6 10^6	,,
253·2	1·580	8·91		5·285	472·9 10^6	Copper.[7]
262·8				5·640	464·3 10^6	,,
270·4				5·910	460·4 10^6	,,
278·7				6·20	458·5 10^6	,,
287·9				6·5325	455·0 10^6	,,
297·5				6·8195	451·0 10^6	,,
308·8				7·3075	448·9 10^6	,,
256·5	1·6145	8·90		4·226	463·5 10^6	Copper.[8]
267·9				4·5625	453·3 10^6	,,
280·1				4·915	446·2 10^6	,,
292·2				5·240	445·5 10^6	,,
301·9				5·532	438·2 10^6	,,
316·8				6·655	791·4 10^6	Soft iron.
322·1				6·88	778·3 10^6	,,
335·1				7·301	779·0 10^6	,,
347·4				7·768	766·6 10^6	,,
366·0	1·357	7·657		8·455	756·0 10^6	,,
39·4	·1745	20·805	20612	2·05	622·25 10^6	Platinm.[10]
65·9	·1825	19·8	10902		281 10^6	Gold.[11]
75·7	·1185	10·21	10967		270 10^6	Silver.[11]

Remarks.

[1] Only forty vibrations from initial arc of convenient amplitude could be counted. Had been stretched considerably before this experiment

[2] So viscous that only twenty vibrations could be counted. Broke in stretching.

[3] A piece of the preceding stretched.

[4] The preceding made red-hot in a crucible filled with powdered charcoal and allowed to cool slowly, became very brittle; a part of it with difficulty saved for the experiment.

[5] Another piece of the long (2435 centims.) wire; stretched by successive tractions.

[6] A finer-gauge copper wire; stretched by successive tractions.

[7] Old copper wire, softened by being heated to redness and plunged in water. A length of 260 centims. cut from this, suspended, and elongated by successive tractions.

[8] Another length of 260 centims. cut from the same and similarly treated.

[9] One piece, successively elongated by simple tractions till it broke.

[10] Not stretched yet for a second experiment.

[11] Added May 27, after the reading of the paper.

Thus it appears that that specific rigidity which is concerned in torsion is very markedly diminished in copper, brass, and iron wire, when the wire is elongated permanently by a simple longitudinal traction. When I first observed indications of this result, I suspected that the diminution in the torsional rigidity on the whole length of the wire might be due to inequalities in its normal section produced by the stretching. To test this I cut the wire into several pieces after each series of experiments, and weighed the pieces separately. The result proved that in no case were there any such inequalities in the gauge of the wire in different parts as could possibly account for the diminution in the torsional rigidity of the whole, which was thus proved to be due to a real diminution in the specific rigidity of the substance. The following sets of weighings, for the cases of the wires of the two last series of experiments on copper, may suffice for example:—

Wire of 308·8 *centims. long, cut into four pieces.*

	Length. Centimetres.	Weight Grammes.	Weight per Centimetre Grammes.
No. 1	109·2	5·023	·04600
,, 2	66·7	3·050	·04573
,, 3	63·2	2·865	·04533
,, 4	69·4	3·143	·04517
	308·5	14·081	

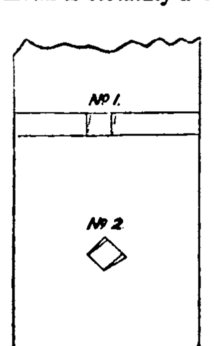
Wire of 301·9 *when last vibrated, further elongated by about eight centimetres when it broke; then cut into five pieces in all.*

No. 1	66·3	3·183	·04801
,, 2	66·4	3·083	·04643
,, 3	66·5	3·039	·04570
,, 4	66·8	3·072	·04599
,, 5	43·4	1·986	·04576

By several determinations of observations on the elongations within the limits of elasticity produced by hanging weights on long wires (about 80 feet) suspended in the college tower, it seemed that Young's modulus was not nearly so much (if at all sensibly) altered by the change of molecular condition so largely affecting the rigidity, but this question requires further investigation. The amount of the Young's modulus thus found was, in grammes weight per square centimetre, 1159×10^6 for one copper wire, and 1153×10^6 for another which had been very differently treated. The highest and lowest rigidities which I have found for copper (extracted from the preceding table) are as follow:—

Highest rigidity, 473×10^6, being that of a wire which had been softened by heating it to redness and plunging it into water, and which was found to be of density 8·91. Lowest rigidity $393·4 \times 10^6$, being that of a wire which had been rendered so brittle, by heating it to redness surrounded by powdered charcoal in a crucible and letting it cool very slowly, that it could scarcely be touched without breaking it, and which had been found to be reduced in density by this process to as low as 8·674. The wires used were all commercial specimens—those of copper being all, or nearly all, cut from hanks supplied by the Gutta Percha Company, having been selected as of high electric conductivity, and of good mechanical quality for submarine cables.

It ought to be remarked that the change of molecular condition produced by permanently stretching a wire or solid cylinder of metal is certainly a change from a condition which, if originally isotropic, becomes æolotropic* as to some qualities†, and that the changed conditions may therefore be presumed to be æolotropic as to elasticity. If so, the rigidities corresponding to the direct and diagonal distortions (indicated by No. 1 and No. 2 in the sketch) must in all probability become different from one another when a wire is permanently stretched, instead of being equal as they must be when its substance is isotropic. It becomes, therefore, a question of extreme interest to find whether rigidity No. 2 is not increased by this process, which, as is proved by the experiments above described, diminishes, to a very remarkable degree, the rigidity No. 1. The most obvious experiment, and indeed the only practicable experiment, adapted to answer this question, will require an accurate determination of the difference produced in the volume of a wire by applying and removing longitudinal traction within its limits of elasticity. With the requisite apparatus a most important and interesting investigation might thus be made.



* A term introduced to designate a substance which has varieties of property in various directions (Thomson and Tait's "Natural Philosophy," § 676.)

† See, for example, a paper by the author, "On Electrodynamic Qualities of Metals," Philosophical Transactions, 1856.

ON TORBITE (A NEW PREPARATION OF PEAT) AND ITS USES.*

By D. K. Clark, C.E.

The writer had occasion a short time since to inspect professionally the works established at Horwich, in Lancashire, to manufacture fuel and charcoal from peat, and was so struck with all that came under his notice, and impressed with the importance of the results obtained, that he feels that he cannot bring a more interesting subject before the meeting. The question of the manufacture of peat into fuel is in reality a question of supplementing the natural supplies of coal with a fuel, which may be made superior to it in every respect, more abundant, and more readily accessible. The consumption of coal is so enormous, and goes on annually increasing at such a rate that for some time past, serious apprehensions have been entertained that our coal measures will be exhausted at no very distant period. Our stock of coal, excluding all that lies at a greater depth than 4000 ft., has been estimated at 83,544,000,000 tons. In 1863 the consumption reached 86,300,000 tons, and the average rate of increase for the last ten years has been two millions of tons a year. Thus, supposing our stock to have been correctly estimated, in less than 100 years our coal will be exhausted. Fortunately, however, nature has not left us dependent on our coal measures alone, but has also given us our bogs.

Peat, it is well known, possesses many most valuable properties as a raw material for fuel, but the attempts hitherto made to utilise peat on a large scale have proved failures, owing to the difficulty of dealing with a substance exceedingly bulky, very loose, and holding from 75 to 85 per cent. of water. To separate the water and to condense and mould the peat into convenient sizes at a cost sufficiently low to render it commercially available as fuel, is a problem which has baffled the efforts of many operators. In most instances compression has been applied, for the purpose of imparting the requisite degree of solidity, by means of powerful hydraulic presses or other machinery. In the process adopted by Messrs. Gwynne and Mr. C. Hodgson, the peat is first dried and powdered, and then pressed into blocks; but the action of compression is purely mechanical, and though it imparts great compactness by bringing the particles of the peat into close contiguity, it does not really solidify the substance, since, on being exposed to heat, it resumes its original form and crumbles to pieces. Fuel thus prepared is totally incapable of resisting the action of a blast or even of a moderate draft, and though Mr. Hodgson still carries on the manufacture of fuel by his process, the consumption is very limited.

According to Mr. Cobbold's mode of treatment the peat is immersed in water for the purpose of separating the fibre from the more decomposed matter, and the water is afterwards got rid of either by simple evaporation or by means of centrifugal power; but though by this meant a very dense fuel is obtained, the separation of the fibre deprives the fuel of coherency, besides which the process is laborious and costly. Attempts have also been made in Ireland to utilise peat by manufacturing it solely for the sake of its chemical products. Many valuable products have thus been obtained, from which even paraffin candles have been made, but the cost far exceeded the market value.

But such attempts have not been altogether in vain, inasmuch as the experience thus gained in the treatment of peat has proved of great value. To know what will not do is a great step towards knowing what will do; and the more recent patents show, almost in the order of their dates, the slow but steady progress that has been made, until one arrives at the system of manufacture recently inspected by the writer at Horwich. According to this system mechanical compression in any manner is studiously avoided, being not only costly, but also ineffectual. Advantage has, on the contrary, been taken of the natural property of peat, suitably prepared, of contracting as it parts with its moisture, and becoming perfectly solid and cohesive. The means of separating the water suspended in the peat have, too, been carefully perfected. The necessity of dealing with, and getting rid of, such a large proportion of water, has been a standing difficulty from the first, and the cause of excessive expenditure. At Horwich the problem has been carefully studied, and the difficulties appear to have been successfully overcome. Until a mode of artificially drying peat rapidly and economically had been worked out, air drying was necessarily resorted to; and where limited quantities of fuel—say about 100 tons a year—only are required to be made, air drying may suffice, but for large quantities it would be, in our fickle climate, too uncertain a process to be depended on, and for seven months in the year it would not be available at all.

According to the system matured and established at Horwich the peat, as it comes from the bog, is thrown into a mill expressly constructed, by which it is reduced to a homogeneous pulpy consistency. The pulp is conveyed, by means of an endless band, to the moulding machine, in which, while it travels, it is formed into a slab and cut into blocks of any required size. The blocks are delivered by a self-acting process on a band, which conveys them into the drying chamber, through which they travel forwards and backwards on a series of endless bands at a fixed rate of speed, exposed all the time to the action of a current of heated air. The travelling bands are so arranged that the blocks of peat are delivered from one to the other consecutively, and are by the same movement turned over in order to expose fresh surfaces at regular intervals to the action of the drying currents, so that they emerge from the chamber dry, hard, and dense. To the peat substance thus treated the name of "torbite" has been given, from the Latin *torbo*, by which name peat is constantly mentioned in ancient charters.

The next stage in the process is the treatment of the torbite in close ovens, when it may either be converted into charcoal for smelting purposes, or may be only partially charred, for use as fuel for generating steam, or in the puddling furnace.

The whole of the Horwich system has been planned with a view to the utmost economy of time and labour. The raw peat is nearly altogether automatically treated by steam power—introduced at one end it issues from the other in the form of charcoal, within twenty-four hours after it is excavated from the bog, and the manual labour expended is almost entirely limited to the first operation of digging, consequently the actual outlay in labour and fuel in the production of the charcoal does not exceed from 10*s.* to 12*s.* per ton; but, in addition to the economy thus effected by charring in close ovens, a considerable quantity of valuable chemical products are yielded, as ammonia, acetic acid, pyroxylic spirit, paraffin oils, the sale of which alone will nearly cover the expenses of the whole process. The fatty matter separated by distillation forms an excellent lubricating grease, the yield of which averages about 5 per cent. of the weight of charcoal produced; in its crude state it has been sold for £12 per ton at Horwich.

The charcoal made from torbite is extremely dense and pure; its heating and resisting powers have been amply and severely tested, and with the most satisfactory results. At the Horwich works pig iron has been readily melted in a cupola. About 80 tons of superior iron have been made with it in a small blast furnace measuring only 6 ft. in the boshes, and about 26 ft. high. The ore smelted was partly red hematite and partly Staffordshire, and the quantity of charcoal consumed was 1 ton 11 cwt. to the ton of iron made, but in a larger and better constructed furnace considerably less charcoal will be required. It has also been tried in puddling and air furnaces with equally good results, considerably improving the quality of the iron melted. For this purpose the fuel was only partially charred, in order not to deprive it of its flame, which is considerably longer than that from coal. Some of the pig iron made at Horwich was then converted into bars, which were afterwards bent completely double when cold, without exhibiting a single flaw. Messrs. Brown and Lennox, in testing this iron for chain cables, have reported that its strength was proved to be considerably above the average strength of the best brands.

In Germany peat mixed with wood charcoal is very extensively used in the production of iron, the peat as prepared there not being sufficiently solid to do the work alone, but it is found that the greater the proportion of peat that can be used the better is the quality of the iron produced. The gas delivered from the high furnaces has also been satisfactorily employed in the refining of iron and the puddling of steel. The value of peat in the production of iron has long been established. Iron metallurgists are agreed in the opinion that iron so produced is of very superior quality. In every stage of iron manufacture, and in welding, peat charcoal is most valuable. At Messrs. Hick and Son's forge, in Bolton, a large mass of iron, about 10 inches square, was heated to a welding heat with peat charcoal made at Horwich. The time occupied was less than the operation would have taken with coal; the whole mass was equally heated through, without

* Read before the British Association.

the slightest trace of burning on the outside, and in hammering out the mass as much was done with one heating as ordinarily required two heatings to effect. The importance of obtaining an abundant supply at cheap rates of peat charcoal cannot, therefore, be too highly estimated.

For the generation of steam the fuel made at Horwich has also been well tested, and its superiority over coal practically demonstrated, both in locomotive and stationary engines. On the Northern Counties Railway of Ireland a train was driven with it from Belfast to Portrush, a distance of seventy miles. The result at the end of the journey showed a saving, as regards weight consumed, of 25 to 30 per cent. over the average of three months' working with coal on the same journey. There was an excess of steam throughout the run, though the fire-door was constantly open and the damper down. At starting the pressure was 100 lb., but during the trip, and while ascending a steep incline, it rose to 110 lb., and afterwards to 120 lb. with the fire-door open. While running there was no smoke, and very little when standing still.

At the Horwich works the fuel was tested against coal under the boiler there. This was done on two consecutive days, the fire having on each occasion been raked out the night previous. The following results were obtained:—Coal got up steam to 10 lb. pressure in 2 h. 25 m., and to 25 lb. pressure in 3 hours; peat fuel got up steam to 10 lb. in 1 h. 10 m., and to 25 lb. in 1 h. 32 m.; 21 cwt. of coal maintained steam at 30 lb. pressure for 9¾ hours; 11¼ cwt. of peat fuel maintained steam at the same pressure for 8 hours. But in addition to this a large economy is effected by the use of peat fuel for the generation of steam, in the saving of boilers and fire bars from the destruction caused by the sulphur in coal, from which peat is free. In Bavaria peat fuel has been used on the railways for several years past, and the economy effected by its use in the wear and tear of the engines is stated by the officials in their reports to be very considerable.

The bogs of Great Britain and Ireland cover an area exceeding five millions of acres, the average depth of which may be taken at 20 feet. Nature has thus supplied us with the means of adding to our stock of fuel some twenty thousand millions of tons. In Ireland about a million and a half of acres have been thoroughly surveyed. In the reports of these surveys it is stated that beneath the peat an excellent soil, well situated for drainage, was found, fit for arable or pasture land. When it is considered what peat is capable of doing, and all the results involved in the question of utilising peat, it is impossible not to feel impressed with the conviction that, in what has been accomplished at Horwich, the foundation has been laid of an undertaking of great national importance and interest.

THE FINE ARTS AND THEIR CONNECTION WITH EDUCATION.

By T. Hayter Lewis.*

In beginning this address, I feel it to be my duty, and a most pleasing one, to refer to my predecessor, Mr. Donaldson. There are few amongst us in our profession who have not experienced his kindness; and I rejoice to know that it was from no infirmity of body or mind, no want of power, that he resigned the position to which I have succeeded: but that, in full possession of every faculty, he has chosen to give place to a younger man; and we may well look forward, so far as one may venture so to do, to his enjoyment of a vigorous and honoured old age.

I have selected the subject of the Fine Arts generally, not because I arrogate to myself any special knowledge of sculpture and painting, but because I hold the only professorship connected with the fine arts which exists in any university in the United Kingdom. Where anything akin to it has been founded—as, for example, in King's College—it really takes no cognisance of architecture in anything beyond construction; and the clever professor there, whose talents could well adorn any one of the subjects which I must teach, is limited to the range of mechanical art and constructive science. Your council has procured for this college the credit of being the only one in which a knowledge of any one, even of the fine arts, has been considered as an essential part of a learned and liberal education. I think that the time is not far distant when such a fact as this will be looked upon as singular enough, and be recorded in the same way as that mentioned with surprise by a well-known German traveller, who, describing one of our greatest manufacturing towns, and thinking of the numberless statues that used to decorate an ancient city, noticed it as his belief that it was the only one in the world, with 100,000 inhabitants, in which there was but one public statue to the memory of the statesman or the soldier who had deserved well of his country, or the citizen who had adorned his town. The one college will, I think, meet with many an equal in future times, as the one statue in that town already has. But there is another reason for speaking of the three fine arts together; the feeling that they ought to be considered in our minds as being parts of one great whole, to be thought of and spoken of in common—that the one without the other is disjointed and fragmentary—that architecture without sculpture and painting is like a strong-limbed tree throwing around its sinewy arms without the delicately sculptured foliage to give it grace, or the beautifully coloured flower and leaf to give it life. The arts are dissevered now, no doubt, in real practice; perhaps still more so in the popular view of them. But look at the result: contrast the bald and lifeless works of the last two centuries (wherein the sculptor and the artist seem to have bid farewell to the architect and the engineer) with the glories of the time preceding—no matter what—when art was vigorous—in Italy and Greece, and, in our own land, in Westminster and Wells, Canterbury and York.

Walk round any of those cathedrals, and see if you can find a spandrel or a panel or a vacant space in which you seem to want the sculptor's art, and see if it be not there applied. Defaced and half destroyed as some of them are, enough has still been left to show us what must have been the full effect when their sculpture was still perfect, and their mouldings and ornaments were glowing with gold and colour. Study the remains which the Greeks have left us, and imagine, if you can, the Parthenon without the sculpture which clothed its form with life, and the painting with which it glowed; or think of that same sculpture dissevered from the glorious frame which binds the whole together into one harmonious whole. They were not things to be resolved into the different phases of framework and decoration, but each formed one essential part of all, without which there could be no perfect unity, without which each would be a lifeless part, a portion only of a perfect whole. But go back to earlier times than even Greece: study, as our museums and libraries may well permit you, the relics left to us by the Assyrian and Egyptian, and of their palaces and temples. No grander outline ever perhaps was left to us than the Pharaohs have left on the banks of the Nile; none more picturesque than those which Sennacherib and his brother Assyrian kings have bequeathed to us from the banks of the Euphrates; and each one of the great edifices has the history of its founder, its nation, its wars and conquests, its kingly customs and domestic life, sculptured on every portal, coloured on every wall. Dissever the three arts in these colossal works, and you would have robbed the buildings of their history, and consigned the sculpture and the painting to oblivion. But I will take one other and a last illustration—I think a very apt one—the graceful architecture of the Saracens: one so light, so elegant, so redolent of the grace and luxuriance of the East, and yet so bold, that no artist could seek a better subject for his pencil, no poet a more graceful rendering of his dream. Seek where you will, you will not find a more life-like embodiment of all that is beautifully delicate to illustrate an Eastern tale. And these Saracens were limited, as we are not, in the designing and decoration of their works: on them their architect dared put the likeness of no living thing. The Eastern workman, as he carved the glorious buildings which the Arabs have left to us in Egypt and Spain and India, dared grave upon it no flower or plant or animated form which might remind him of his native land; and seldom, very seldom, do you find upon it one form, the likeness of anything upon the earth, which contravenes the Prophet's order. A form of beauty was, with the Mussulman, a thing to be fashioned out—created, as it were, in his own mind, beyond the realm of nature; for the great source of wellnigh all that we think beautiful was with him a blank. Yet see how, with the inborn sense of the beautiful within him, he created forms unknown before, special to him alone, and "with light by one entrance quite shut out," was able to lavish upon his works the bewildering mass of sculpture and painting which adorns them, and which he has worked into them, not as a decoration only, to be put or withdrawn at pleasure, but as part of their very being, their life. Dissever from his works—from the works of the

* Lecture delivered at University College, London.

Gothic architects, the Greek, the Assyrian, and Egyptian—from any race whose works have been preserved to us and are worth preserving—either of the three arts, and you leave in them a most painfully apparent void. Not that I seek to urge the loading of a work with ornament: I know too well that ornament, of whatever kind, may be added to a surfeit; but until the three sister-arts are joined together more closely than they are, and until each one is valued as much by the assistance it gives the others as by its own intrinsic worth, we may expect and shall assuredly meet with extremes of redundance and of poverty.

Now look at the history of the men to whom we owe the works which I have described, and whose memories, if even their names have perished, shall live for all time. We smile at the old writer, when he tells us that the architect must be at once skilled in literature, erudite in geometry, familiar with history of all periods and countries, acquainted with philosophy, music, law, the aspects of the heavens, and the influence of seasons and climate. But trace the actual lives of many of the men to whom we owe chief art-works, and you will find his dream has welluigh been realised. We scarcely realise it ourselves. How many of us are there who, standing entranced before the beauties which Da Vinci has traced upon the canvas and the wall, pause to remember him as the sculptor, the architect, the engineer of his age, and the first geologist on record! How many who pace the Loggie at Florence, or gaze upon its richly-coloured cathedral walls, think of Arnolfo, sculptor as well as architect; or of Orgagna, the painter, poet, and sculptor, who chiselled with his own hands the sculptures upon the edifices he designed! Do you wonder at the marvels which we owe to Giotto's pencil? Think of that glorious campanile which we owe to him as architect. Do you tread at Pisa with reverential feeling the sacred field of the dead? Remember that it was Giovanni the sculptor who designed it. Look at the glorious outline of our St. Paul's, never, to my mind surpassed, and recall to your mind that its architect was at the same time the first geometrician and astronomer of his age. And when you think of the heaven-like beauties which Raffaelle drew—of the prophets and the sibyls which awe us still in the Sistine chapel of Buonarotti, of the unearthly grandeur of his statues which adorn the churches of Florence and of Rome—remember that they came from the same hands which designed many a palace there, and to whom we owe the grandly towering dome of St. Peter's and the splendid façade of the Farnese. Now, in considering the works of these great men, we must remember that they are the chief outward visible embodiment of their country's glory and power and skill. True it is that the historian will, in the glowing pages of his book, commit to immortality the stirring deeds, the conquests in the moral and the material world, which adorn the history of his nation, more vividly and more truly, with as great power and skill, as the artist will in depicting them upon the canvas. The poet and musician will sing them in melodies which shall raise the thoughts beyond the things of earth, and for the time transport us to the outer world; and the philosopher, with far research and deepest thought, will penetrate into the outer and inner world of nature, and bring forth their secrets for the use of man. And all these men shall help to immortalise the nations of whom they form the chiefest ornament, and shall themselves be honoured through all time. But the actual visible marks of their country's greatness are the monuments which the architect, and the sculptor, and the painter have left upon her soil. The stranger from a far land will walk the aisles of Lincoln and of Westminster, and see in their wondrous beauty the realised embodiment of the nation's skill, though he be ignorant of the histories, nay, of the very names, of the illustrious dead whose monuments perchance ornament or disfigure its walls, and whose memories cast a halo around them in the eyes f those with whom their names have been household words.

And you will pace the grand cathedrals of Strasburg and St. Marc's, and be hushed into general awe at their beauty and their grandeur; and, Protestants as you are, almost bow down and worship as you hear the solemn strains which speak to us in harmony with all around, and seem to breathe the very soul of Alleghri or Mozart. You forget the great ones of France and Italy, and think only of the works which the architect, and the sculptor, and the artist have raised and adorned. Not that the fame of historian, or poet, or philosopher is by comparison diminished. Their works are before your eyes, their words graven upon your minds and lastingly present with you; whilst the effect of a work of art is soon diminished—often, perhaps, lost, but whilst present it is to you the outward symbol of a nation.

And in every time since detailed records of it have existed, these great works of art have been more than the visible signs of the presence of great, exceptionally great minds. They have been, too, the sign of progress in intellectual power and skill of the general body of the nation, of whose advance the illustrious men of whom I speak are the mere striking representatives. The palace or cathedral is not a mere exceptional work, to be studied and admired as something quite beyond the ordinary verge of art, but as the mere culminating point of it; not a mere isolated peak standing as a landmark for all time, and utterly disengaged from anything around, but as the summit-point of the minds and works of a people with whom art was ever present, and amongst whom the appreciation of form and detail was innate,—who had been so used to see the beautiful or severely true before them in every stage of ordinary life, no matter how trivial, how common, that they had been self-trained, unknowingly taught, and educated to understand and appreciate, and practise it.

It is from the general training and education of a people that must ultimately come those greater efforts of the mind which some would seem to think may rise spontaneously from the barren soil of ignorance in art. Think if it ever did so. Look at the objects now gathered into our museums as things for us to value and study, classed now as works of art, beautiful alike in form and detail.

Why, one half of them were the mere household goods of the Roman and the Greek,—the ordinary accompaniments of the Mediæval convent or church. You stop at a lovely bronze, a delicately-moulded piece of earthenware, and a delicately-tinted page, and you find that it was a lamp that lighted their chamber, —the frame of one of their little mirrors,—the missal which they used at prayer. You will pass—the most skilful of us will pass—many an hour before we design anything more graceful, yet more useful and more true withal, than the common household pottery of the Romans,—their wine vessels, the very spouts which took the water from their roofs, the utensils of the kitchen, the ladles, and the great bronze cauldrons which they used there. And think of the skill which the common blacksmith of our country showed in the commonest things of use,—the handle of a key, the hinge of a door, the cover of a book.

All these things, though looked upon (as indeed they are) as art-relics now, were not made up for us to see, as something special to be put aside as things for study. I doubt if the most advanced of Romans ever dreamed that the things his servants used,—the lamp that lighted his chamber, his ladles and his cauldrons, would be considered of so great value as to form the ornaments of a museum. And little did the village blacksmith think, as he forged the massive hinge or chased the delicate little key, that it would be covered up in after-times in a glass case, as a thing to be admired, and considered, and talked about as one that we would equal if we could. And even less, perhaps, did he imagine that, in a few centuries only, and in his own land, the very traditions of his work would be so lost, that the fabric of the metal, the design in which he worked it, and the method of its working, would all be studied as something to be learned.

And yet it is so. Few there are, comparatively, of those who visit our galleries and museums, and admire (sometimes not that) the mass of artistic wealth they see there, who realise to themselves the truth that it is, in the main, a collection of common things,—of household goods,—as much the things of ordinary life as the willow-pattern plate or the threaded fork with us.

Will it be the same with us? Will the ordinary fittings of our households be ranged as things of beauty in the museums which our descendants will form? Will the New Zealander of Macaulay place our works by the side of those of the Roman and the Goth, as food for study and instruction? I fear not. Few, I think, will say they will. Many, perhaps, will scarcely think it of any consequence whether what we do is worthy of being preserved or not. But, believe me, if art be not so commonly diffused amongst us—if it be not so for appreciated—so made part of the mind of our people that its presence may be made visible to them in the most common things of life as well as in its most refined, if they be not in fact so educated by the constant presence of art to grace of outline and harmony of colour, as to have an almost intuitive perception of what is good and beautiful and true in outward things, we shall never attain to that excellence in minor things, nor be able to develope them into those higher ones which we admire, and envy, and wonder at

In those times whereof I have spoken, art was in fact everywhere—with the lowly workmen as with the wealthy world who employed him. You cannot investigate the history of any period of ancient or Mediæval art without discovering that not only the master who designed the work had a full appreciation of the beautiful or quaint, but that the man who carried out its details—who worked its mouldings, carved its sculpture, and tinted it with colour and with gold, was in himself, in his own humble way, an artist, appreciating the beauty of the whole and the value of his own part in it, and showing by some little variation of design, some turn of a leaf, some free movement in the foliage, that he acted in the doing of it from his own resources, and that the work was stamped with his own feeling as being in some sort his own, and not the mere literal rendering of another man's ideas. And this independent feeling, which made him trust in some sort to himself, gave a life and freshness to it which a mere copy never could. No mere copyist, too, could ever much love his work; and if he do not, there is little chance of his doing much that is worth the loving.

Now, with our museums and art-schools, and still more by the general interest which has of late years been taken in all that relates to art, we have no doubt, done much. But try now, in anything beyond the commonest range of the square and rule (and so far, no doubt, our workmen could scarcely be excelled), and leave them to carve the stone or to forge the iron into forms of quaintness or of grace, or to give the silver or the gold a beauty such as was found with it when the quaint old goldsmiths used to work it, and (with exceptions happily more common now than they were wont to be) one quickly finds that they are altogether lost, and that the stone and metal are taking forms which, although quite their own, have scarcely the recommmendation of quaintness or of beauty.

But worse than that, I fear, I much fear that the workman's skill, be he skilled ever so much, would scarcely be so appreciated by the general world as to allow him much reward. Yet there is hope for the future. There is no want of interest in it in any of its phases—no want of admiration of the great works which adorn our own and foreign lands. But admiration is not knowledge—sometimes, we well know, quite otherwise; the subject of it is oftentimes an unworthy one, and the danger is that the two may be mistaken for the same thing,—that the pleasure which all must feel in looking at a work of art may be judged to be the result of an innate power of appreciating it—a power which would make a special study for obtaining it quite useless. As if the admiration with which we hear the eloquence of an advocate could fit us for the practice of the law,—as if wonder at the skill by which there is built up, from a few dried and broken and discoloured bones, the whole body of the extinct denizen of a former world, could give to us the art of the anatomist. And of all ignorance none can be so great, so helpless, as that of one who, knowing little or nothing of a subject, is thoroughly well satisfied that he knows it well. Your eye may, indeed, by habit or association, be brought to such a state of perfectness as that the good and the bad may be discerned by it without a special study. But then, that case is the very one I put before, viz.—that of a constant presence of and association with correct and harmonious forms and colouring, giving of themselves a constant lesson of the beautiful; and we are very far from having arrived at that state yet.

Rely upon it, art has a grammar to be learnt as much as language has. A certain amount of study—I might almost say of drudgery—has to be gone through, before the understanding (set aside the practice) of an art can be mastered.

It is, I think, scarcely necessary for me to plead on behalf of art and of its diffusion. I know that it may be said, and it is indeed a matter of some wonder, that the knowledge of the beautiful is most conspicuous in the nations of the East, enervated, treacherous, and fierce. But all their art came to them traditionally with their blood. You see in them the relics only of the skill and taste which made the capital of the Persian kings the great store-hive of all which was most beautiful and grand in art. It is passing away now, as their power has passed; and many a lovely work, which, but a few years since, would have been one of mere routine, could scarcely now be done at all. It was not their artistic knowledge which has debased them; they have been debased in spite of it, and in their debasement are gradually losing it. But I have heard it said that the full appreciation of the beautiful is a gift reserved for the nations of the South and East—India and Persia, Italy and Greece; that art here can never have a genial growth; that we may perhaps improve in it, but never excel. Never excel! Can we Northmen forget Westminster, and Wells, and Lincoln? Why, when Giovanni was sculpturing his Pisa pulpit (a world-famed work), the niches at Wells were being filled; and, all Classic as he was, Flaxman admitted that, though the sculpture is rude and severe, it has a beautiful simplicity and grace, often excelling the productions of modern times. True, the name of their sculptor is lost. So is the name of many another artist of Mediæval times, who worked in his cloistered cell, and of whose memory and record nothing survives. Truly illustrious instances of utter self-negation. But that they were Northern if not English men, there is no doubt. I know that William of Sens began the glorious choir of Canterbury, but I know that English William finished it. And, to come down to later times, Wren was no less English when he designed the spires (his own creation they are) which so adorn our city, because he went for the details to the same source as the Italians did.

But it has been said, too, that opinions are so different in questions of the arts;—there are so many schools, and each with such ardent advocates, that nothing can be taken as truly certain; and to understand them even, would seem to be attempting a hopeless task. Now, do you find agreement in theology, in medicine, in music, in anything, in fact, worth fighting for? But in every case there is a certain groundwork, a solid stand-place from which all disputants take their start, and it is only when that is quitted and we enter into the more subtle details that we begin to differ. And it is that groundwork only that I want taught. Some will stop there. Others, more captivated, will be led by study or association to follow art in her various paths, each in his own. But in any case, the means by which he reached the standing-place will have brought with them some better appreciation of the beautiful than he had before, and, rest where he will, will not be altogether lost.

To descend to details. I fully believe that, in order to be able thoroughly to appreciate the beautiful in form, one must as a general rule be able to draw it. Some minds of course, may, by an otherwise cultivated taste, have arrived at a high standard of it; but this is rarely found. Be this, however, as it may, no one who has been well accustomed to mark with his own hand the graceful flow or contrasted curve of a line, could fail to see the want of grace in an object that he was making, or that he was about to buy. Get so far as this on the one side with the mechanic, on the other side with his patrons, and we have got a very long way on indeed.

I believe that if in the schools of our little villages, as well as those of our great towns, each youth were taught to know, by drawing it with his own hand, what is graceful in form; if he were taught to draw, with the special object of showing him that one outline is beautiful and another is not; if he were shown, with the things before him and his own hand to mark it, the beauty of the common things he sees about him—the curve of the ear of corn as it bends gracefully on its stalk, the veins of the wavy leaf, the delicate drooping of the willow bough, the contrasted curve of the chesnut or the oak—we should in a short time have affected a mighty change. I do not say you would have taught these things to all; not a twentieth part, perhaps, of those who at first learnt would very much appreciate them. You cannot make clever scholars in anything, no matter what, if there be not the wish to learn, or the special genius to apply. But you would have given all a chance, and many a time developed a latent power otherwise lost. And many a clever mechanic, who now does so excellently well exactly what he is told to do, and no more, would have a chance of being able to work up a thing in whose designing he has had some hand. And those of the ranks above, whose knowledge and requirements cause them to be, to a great extent, the arbiters in things of taste,—of how much value would their knowledge be had it been directed specially to the beautiful in form, in place of the poor conventionalities now taught? A tree is a thing one is taught to draw, because to copy it is difficult. I have seldom heard of its chequered and rugged bark, the massive sweep of its boughs, or the delicate curve of its leaves and tendrils, being marked out as things of beauty, and specially to be drawn as such. And if not put upon this path, your drawings will scarcely be of much use, so far as my object goes. I think that I can see some change that way; but it is not easy in any subject to make a likely guess, when the time is very limited. To use a simile not my own, we are there as one looking at the tide on the sands, and watching the unquiet sea. Sometimes a great wave will overleap the rest, and dash up to your very feet, and you will think the great sea is coming in. And then will come many another, smaller and more gentle than the last, and you will think that the sea is surely falling back. So it is with art. Sometimes a great work is done, and we think that the man who did it is a forerunner only of many another, and that we are to see the olden times again. And then there comes a dearth in art, and all looks blank. But I hope now for the best.

I wish now, in a few words, to point out to you, my hearers, whose training and education have been of the higher class, the attractions which the arts will offer; how fascinating to yourselves, how useful to others may their study be in ways quite different from those in which they usually are studied. No one here but knows that it is within a few years only that new chapters have been added to our history by the unlooked-for discoveries of Layard in Assyria. Much the same has been done in Egypt. And how has this been done? The page of history was silent. Every line which Herodotus is said to have written on Assyria has been lost. Of the earlier times of Egypt all that we know wellnigh is from the list of kings—a bare barren list, understood by none, altogether disbelieved by many. There is enough, just enough, in Holy Writ to excite our curiosity and wonder, but nothing more; and the grave appeared to have closed for ever over the records of those mighty kingdoms, whose grandeur would seem to have surpassed all that the world has witnessed since. We know it now. We have seen the great cities of Assyria disinterred, and on the walls of her palaces and temples we find graven the sculptures which the Jewish prophets saw when Nineveh was the capital of the great Assyrian king, and in this sculpture we read her history.

Strike from the list of things that are what men call ornament. Strike out from the cities of the nations the works of the sister-arts, and those bright pages of long-lost history would have been lost still—utterly, irrevocably lost. But there is more even than this. We all know, as household words, how Rome and Carthage, Athens and Thebes, were founded, and in the simple stories willingly forgot or soberly disbelieve the facts whereby the historians of our day have shown them to be well-nigh myths. But they show no more. Our old belief has been destroyed, but we get no certain other in its place. Go back some four or five centuries only before the time of Philip the Macedonian king (a space no greater than from our time back to our second Richard), and the guides of our written history disappear, and their accounts are lost in the dark and gloomy fable.

How shall we recover the lost chapters of our early race, peoples of whom the Bible gives us but uncertain glimpses, of whom the father of history speaks only with dark and doubtful words? Who shall tell us the deeds of, and what our nations owe to, that mysterious race who has left upon our country and every other in Europe, and in Africa, and in all Asia between us and India, those stupendous works which, in our utter ignorance of their authors, we call Celtic, or Druidical, or Pelasgic? How shall we find the solving of that riddle of the Western world—the sudden coming of a Northern race, whose ancestors and whose native country are alike unknown, and introducing or working out in a few years a state of civilization in Mexico and Peru, which was as much the astonishment of its first discoverers as it is now? Or how recover the annals of that people, one of the mightiest that ever overran the earth, who, Lycian, Etruscan, Greek, whoever they may have been, seem to have formed the groundwork of all that was grand in the nations of Greece and Rome? Not in the pages of history will they be found. Those pages have all been scattered to the elements thousands of years back; and if ever their annals are recovered, it will be by the records of the arts, as it has been with Assyria and with Egypt. And not only will this be from the characters on the walls—the Greek-like writing of Etruria, the Runic lines of the Druids. There is not an ornament, a moulding, a change of style in the sculpture or the painting, that will not come to the aid of the careful student. It will help to tell him what the race whose history he investigates has borrowed from the other known nations around; how it has improved, or how deteriorated. For, strange as it may seem, the history of the races of mankind may be studied, and to some purpose studied in a bold general way, by the traces which they have left in their architecture, their sculpture, their painting; and as the earth can be boldly marked into definite tracts of strata by the fossils they contain, so these fossilised artistic works of man will tell as truly of the extinct race who reared them. And the change of these races as one swept over a country and dispossessed another, will be as plainly shown by the works they have left behind, as change from one fossil to another shows that we have passed from the strata of the silures to those of the oolites. We have no scale of time as yet in either case, but we have a scale of succession; and the help which that gives us is immense.

And thus it is that though the state of art in the early ages of the earth may at first sight seem scarce worth notice now, you will find its study of a deepening interest, although the name and memory of the earliest of the nations may for many a century have passed away. It is the same with art of later date. You can tell in a Gothic building the nation by whose artistic influence the mouldings were shaped, the sculpture cut. You can tell within a few years the time at which each part was done; and there is as much difference in the enjoyment of the beauties of a great cathedral or a village church by those who understand these things and those who do not, as there is between the feelings of a botanist or geologist and of one ignorant of their arts, as they look at the splendours of a botanic garden or the finest series of strata or of fossils.

But other questions still suggest themselves in studying the higher branches of the Fine Arts. One cannot carefully consider the details of the works to which I have alluded in Egypt and Assyria without being struck by the discovery that the earliest works of art are in many a case the best; that some luxuriousness of detail and many a grace, perhaps, were afterwards added; but that a force and energy were shown in the earliest works never exceeded in the latest. Now see what a new world this opens out to us. At the time when the patriarch Abraham and his tribe were wandering shepherds, not only did there exist in the plains of the Tigris and Euphrates a civilization and advance in art which move our wonder now, but that at that early time art had advanced to almost the utmost limit to which the great Assyrian monarchy ever carried it. What thought does that not give us of a distant world, far reaching beyond the narrow boundary fixed by our present knowledge, and how does that boundary which once appeared its utmost limit seem but a barrier hiding the times beyond!

Whence came this civilisation and these arts? From some great and earlier nation still, the memory whereof has perished? Or was the Assyrian or the Egyptian itself the great primæval race? And did the art of those early times come gradually and painfully into being; or did it spring, as I believe it did, and as the legends of the Greeks would have it, in its full strength, all armed, as Minerva sprang direct from the god,—as little a creation of man's as language is?

Have we ever had, in any case, in any time, a clear authentic record of an advance in art and civilisation from the lowest point to the highest? Is it not, rather, the result of all experience, that when a nation's art or industry has suffered change, it has come, not from the unassisted mind of the nation itself, but from some altogether different influence of another race, conquering or civilising as the case might be, and bringing with them their own peculiar style of art to mix with or supersede the other?

We know no more of architecture in its beginning than we know of the origin of language; nor of any of the higher branches of intellectual knowledge, which seem to have been favoured gifts from a higher Power than ours to some favoured nations. But we do know that, so far from art having gradually emerged, as a matter of ordinary progress, from the necessities of mankind, it is quite certain that it never has appeared at any time, except amongst those nations who have derived it direct from the banks of the Nile, the Euphrates, or the Ganges; and that these three came from the same source can scarcely be denied.

Wherever insulated from contact with these favoured nations, no power of mind or body has been able to raise up to a state very much beyond the savage any other race whatever. One exception may be cited, viz., the civilisation of Mexico and Peru. But we are utterly ignorant of the conquering or civilising races there, and the whole is at present, an utter enigma. The arts rose, too, where they did rise, to perfection, not by a steady gradual progress, but by a series of waves, as it were—suddenly rising to the summit, slowly curling over, and then, first hurriedly and then with more gradual course, sweeping over the sands of time: sometimes to be there altogether lost, and sometimes to be urged on again by some new force; but never from the same direction.

The story of the arts has ever been that of a nation's power and of all civilisation, since records have existed; and a more fascinating study—one that would lead you to higher thoughts—I do not believe exists.

And now a few words to those who are about to make my profession a study.

The course marked out for them is a wide one—the history of the art of all nations; and truly it forms so clearly connected a series, that it is hard to say where one can stop with any definite mark. But I wish this all to be studied as a history only; to be thought of just so much as, and no more than, in an architectural practice, the laws and usages recorded in history affect us now at our present time.

And above all, do not imagine that because you have so studied you can at your pleasure take up their several styles, and practise them, and make them your own. You may indeed be called upon to do so, as we all are at some time or other; but do not suppose that this is a matter of indifference, and that you can work in your own practice upon many styles with a chance of success. Depend upon it, it is hard enough, as you will find, to excel in one only.

Now, when we are wandering in so many ways, and so much doubt is felt as to which is the right, it would scarcely be right for me to indicate the path; but what I wish to impress upon you is, that you should mark out for yourselves one clear, distinct, definite course of study in architecture and all that relates to it, and keep that one prominent in all you do. Do, as all must do in other things who hope for excellence in them: fix your mind steadily upon one, and follow it to the utmost.

One word more, and I have done. Your course of study will embrace more than the mere history of an art. It will take in, too, its ordinary practice and all those several branches of knowledge connected with it. It is only in a general way that I can teach them, for time will allow no more; but I would urge most earnestly upon you that you satisfy yourselves as you go on that you have obtained a solid groundwork in them; that you have clearly and distinctly understood the general laws of each. If not, consult the various authorities whom I shall indicate until you do so. Leave details if need be, for future study, as time or occasion may suggest. There is a vast difference between raising for yourselves an edifice complete in look but fragile in reality, and laying the foundation of a solid one, to be finished hereafter, thoroughly well, at your leisure.

And to conclude, speaking to those who have the battle of life to fight, and their own way perhaps to work unaided upward in a world where chance and talent go for much, but steady enterprise for more, I would say, in the words of that Book which we all learn when young, but value perhaps at its full worth only in our riper years, "Whatsoever thy hand findeth to do, do it with thy might."

EXTRACTING GOLD FROM AURIFEROUS ORES.*

By H. Jackson and W. A. Ott.

Amongst the different improvements lately adopted for the extraction of gold from auriferous ores, the process of Prof. Plattner, of Freiberg (Saxony), occupies the first range, as well for its ingenuity as for the advantages to be derived from the same. In this country, on the contrary, the quicksilver or amalgamation process is almost universally practised, and each improvement which possibly could be made has been adopted, so that it may be said the process of amalgamation has arrived at a point where still better results cannot be expected. Though well known and extensively practised for many years, nevertheless it is not free from considerable defects, which, in relation to economy, never will be obviated. This is a fact generally acknowledged, and the process of amalgamation would have been abandoned if there should exist a more practical and improved mode of extracting gold. The said process of amalgamation cannot be applied advantageously to the treatment of poor ores, on account of the great division or distribution of the gold, thus causing an imperfect contact with the quicksilver, and consequently an imperfect amalgamation. Numerous trials and experiments have proved the impossibility of avoiding these defects, even if the operations of the amalgamation are conducted with the most scrupulous care.

For these reasons Prof. Plattner, one of our most ingenious metallurgists, suggested the extraction of gold by means of chlorine, which has been introduced at Reichenstein (Prussian Silesia), where immense quantities of certain auriferous residues from the preparation of arsenic had been accumulated during several centuries. These residues being extremely poor of gold, and not fit for being treated by any other known means, nevertheless afforded a considerable profit by the treatment with chlorine. The same satisfactory results have been obtained at Schemnitz and Schmœllnitz, in Hungary, and other localities, where large hills of residue, formerly considered worthless and thrown aside, are worked over again, and every trace of gold extracted. Plattner, perfectly posted up in theory and practice of all metallurgical operations, soon came to the conclusion that his process might undergo an alteration or improvement in relation to the treatment of natural ores, and especially such ores as contain the gold in a mineralized condition, but, by his premature death, he was prevented from finding out such improvements. Since Plattner's death nobody on the other side of the Atlantic has taken particular pains to apply his process to the treatment of natural ores, for the reason that gold-bearing ores are comparatively rare in Europe.

In order to explain the defects of this process, we deem it necessary to go into some details, and to report afterwards on the method of extracting gold, for which letters patent of the United States have been granted to us in the month of April 1865. Previous to the treatment of chlorine, the ores must be pulverized as finely as those which shall be submitted to the process of amalgamation. Ores containing sulphur must be roasted until all other metals contained therein have been transferred to the highest point of oxidation, being in this condition but very little attacked from chlorine, while gold almost alone will be dissolved. The ore thus first prepared is carried into earthenware jars or wooden barrels lined inside with lead, and chlorine gas is passed through the ore so as to impregnate it thoroughly. After this operation, lukewarm water is to be poured over the ore; the resulting filtered lye of gold is precipitated by sulpho-hydrogen, and the precipitate thus obtained from the sulpho-combination of gold and other metals is dissolved in aqua regia, and by an addition of sulphate of iron the metallic gold will be obtained in a finely divided condition, free from silver or copper, and fit for direct melting.

This treatment answers perfectly well for quartz containing gold in very small particles, and for ores containing very few sulpho-metals, and requiring no completely and costly desulphurization, and it answers also for residues, though the apparatus prescribed by the inventor does not allow operations but on a small scale. For treating ores rich in sulpho-metals, like our ores from Colorado, the application of the said process meets with two serious inconveniences, viz.:—1. An excess of chlorine is necessary: and 2. The remaining ore is very seldom completely exhausted, and contains still some gold. If we examine specially these two faults, we find that the cheapest mode of chlorinizing would be, if just as much of the chlorine gas could be used as might be necessary for the dissolution of the quantities of gold contained in a certain ore. But that, perhaps, never will be the case, and we always shall need a large portion of chlorine; whereas the finely divided ore, and particularly the oxides therein contained, will absorb the gas without binding it chemically.

According to Plattner's plan of treating the ore, a considerable quantity of gas must be lost, and consequently the expenses will be increased the more as the ability of the ore for absorbing the gas may be very strong, and as the prices of the acids and other materials necessary for the preparation of the gas may range high. If this inconvenience cannot be set aside completely, it is however possible to do so partially, in a manner we cannot describe here more particularly. It may be enough to mention that, by applying a peculiar desulphurizing process, we save near one-half of the amount of gas from that required at the works of Reichenstein. This is the first advantage afforded by our process.

In Plattner's process another inconvenience is to be found in the following:—In consequence of an imperfect roasting and of the existence of basic salts and sulpho-metals, combinations of chlorine and sulphur may be created, which, while producing a secondary decomposition, will exert an influence on the chloride of gold already formed, and will separate a quantity of the metallic gold proportional to the quantity of the sulphur thus

* From the Journal of the Franklin Institute.

being lost for the process. A complete roasting, going as far as to remove every trace of sulphur, no doubt would be the best means of obviating this inconvenience, but whoever knows the difficulties occurring in the practice, particularly when operating on copper pyrites, will give up the execution of such a plan.

In our process we obviate the precipitation of the gold in a different manner, that is, by substituting hypochlorous acid (a gaseous body consisting of 1 eq. chlorine and 1 eq. oxygen) for the chlorine gas, and by submitting the ore to the effects of this gas. The hypochlorous acid gas, when brought in contact with the combinations of sulphur remaining in the ore, experiences a decomposition, the oxygen uniting with the sulphur and transferring it into the highest degree of oxidation, while the chlorine combines with the gold. By the application of the said gas to the process of extracting gold, we are enabled to secure two important advantages, viz.—1. We obviate entirely the formation of injurious agents by means of the oxidizing effect of the oxygen; and 2. The chlorine is acting while in *statu nascent*. In this state the chlorine has reached the highest degree of chemical affinity, thus making our process (besides its ability of promoting the close of the operation) applicable as well to ores containing gold in finely distributed particles, as to such ores which may contain gold in coarser particles.

Having explained the two chief points which distinguish our process from Plattner's mode, we deem it necessary to say a few words in regard to the question whether it is applicable in a large scale. Our process requires, like all others, a complete pulverization, and next a good roasting, if the ore should contain sulphur. In case the ores should contain copper, it would be advisable to submit them to a roasting, and to extract the formed copper salt by water, and to precipitate the copper by proper means. In both cases the ore is ready for being treated by the hypochlorous acid. The question now arises whether this gas can be produced at a sufficiently cheap rate. In view of the enormous quantities of it produced for the preparation of bleaching salts, and especially of chloride of lime, we may confidently give an affirmative answer. We do not need for our purposes any other apparatus or localities than those required for the manufacture of the before-mentioned articles, except a leaden retort, which should be placed between the generator of the chlorine and the buildings for the storage of the ore. This retort is filled with a solution of sulphate of soda or glaubersalts, and we thus obtain the hypochlorous acid in a free condition.

The generator of the chlorine, in proportion to the impregnating chamber, requires smaller dimensions than those necessary for the manufacture of chloride of lime. The impregnating chamber is constructed from silicious sandstone or from bricks in a longitudinal form, and represents a room rather more high than wide. It must be coated inside with asphaltum, and boards 8 to 10 feet long and 2 feet wide should be fastened horizontally along the large sides, one above the other, allowing spaces of about 4 inches between them. These boards are designated for receiving the ore. In the middle of the building a small gangway is to be left; two windows allow to watch the operation, and one door affords admittance to the chamber. A green colour will be observed at the windows when the impregnation is completed, and the door, thus far tightly closed, then may be opened for the exit of the gas and for the removal of the ore.

The next operation, viz., the extraction of the ore, is performed either by centrifugal power or by a hydraulic press and water. In this manner we obtain a very concentrated lye, from which we precipitate the gold either directly by sulphate of iron, or by a treatment with sulpho-hydrogen and subsequently by sulphate of iron. Both operations are very simple, and do not require any particular or costly apparatus.

Compared with the process of amalgamation, and in consideration of the expenses for putting up such an establishment being equal, our process, besides the before-mentioned advantages, affords still others, viz.—1. The value of the materials entirely disappearing out of the operations is considerably less, whereas we are working with materials far cheaper than quicksilver. 2. We save great expense of fuel, indispensable for the distillation of the quicksilver. 3. We need no refining, pure gold being precipitated from the solution of the chloride of gold. 4. Our process is not injurious at all to the health of the operators.

ON SOME OF THE RECENT DISCOVERIES IN CHEMISTRY APPLIED TO ARTS AND MANUFACTURES.

By Dr. F. Crace Calvert, F.R.S., F.C.S.*

One of the most curious and important applications which have lately been made of chemistry to manufactures is that of coal gas as a means of obtaining intense heats. In fact, heats have been secured which far exceed those previously obtained by the combustion of coals and other carbonaceous matters. To understand how this result has been effected, it is necessary to refer to the combustion of coal gas. When coal gas is ignited, the oxygen of the atmosphere first combines with the hydrogen of the hydro-carbons, either gaseous or sufficiently volatile to assume a gaseous form, so as to produce water. Whilst a part of the carbon of these hydro-carbons combines with the oxygen to produce carbonic acid, the other portions of carbon float in the mass of ignited gaseous matters, and reach a sufficient temperature to radiate light in all directions. It follows, therefore, that the richer the coal gas is in hydro-carbons, into the composition of which enters a large proportion of carbon, the more brilliant will be the flame.

This is beautifully illustrated by an invention of the Rev. Mr. Bowditch, of Huddersfield, who has lent me one of the apparatuses which he has lately invented to increase the illuminating power of inferior coal gas, and which has been applied with success in the city of London by its learned officer of health, Dr. Letheby. It consists in the introduction of carburetted hydrogens, rich in carbon, into the flame of ordinary coal gas, thus enhancing in a marked degree its illuminating power. This apparatus consists of a gas-tight metallic vessel, which holds the hydro-carbons, and which has an inlet connected with a gas supply and an outlet connected with the burner. The gas in its course passes over the surface of the hydro-carbons. Being above the flame, the vessel and its contents become heated, and part of the latter is converted into vapour, which the passing gas carries with it to the burners to enrich the flame.

The following are the advantages which Mr. Bowditch's apparatus presents:—Common coal gas, Ashburton flat flame, fish-tail, and batwing, does not yield a light of 1·5 standard sperm candles per foot, though it yields the light of 2·4 candles per foot when burnt in a 15-hole argand with a 7-in. chimney. By adding 31·5 grains of naphthalin vapour to each foot of this gas the light-giving value is raised to between seven and eight candles per foot, according to the constitution of the gas with which the vapour is burnt. Oils do not yield quite so high a result as naphthalin, but they afford from 4·5 to 5 times the light given by gas alone. To show the economy of gas, I may cite the following results, given to me by Mr. Bowditch:—A gallon of oil, sold retail for 2*s.*, is capable of producing, with 1000 feet of London gas, more light than is given by 4000 feet of gas; or 4*s.* 6*d.* gas and 2*s.* oil against 18*s.* gas alone. The hydro-carbon vessel requires charging about once in 14 to 16 days.

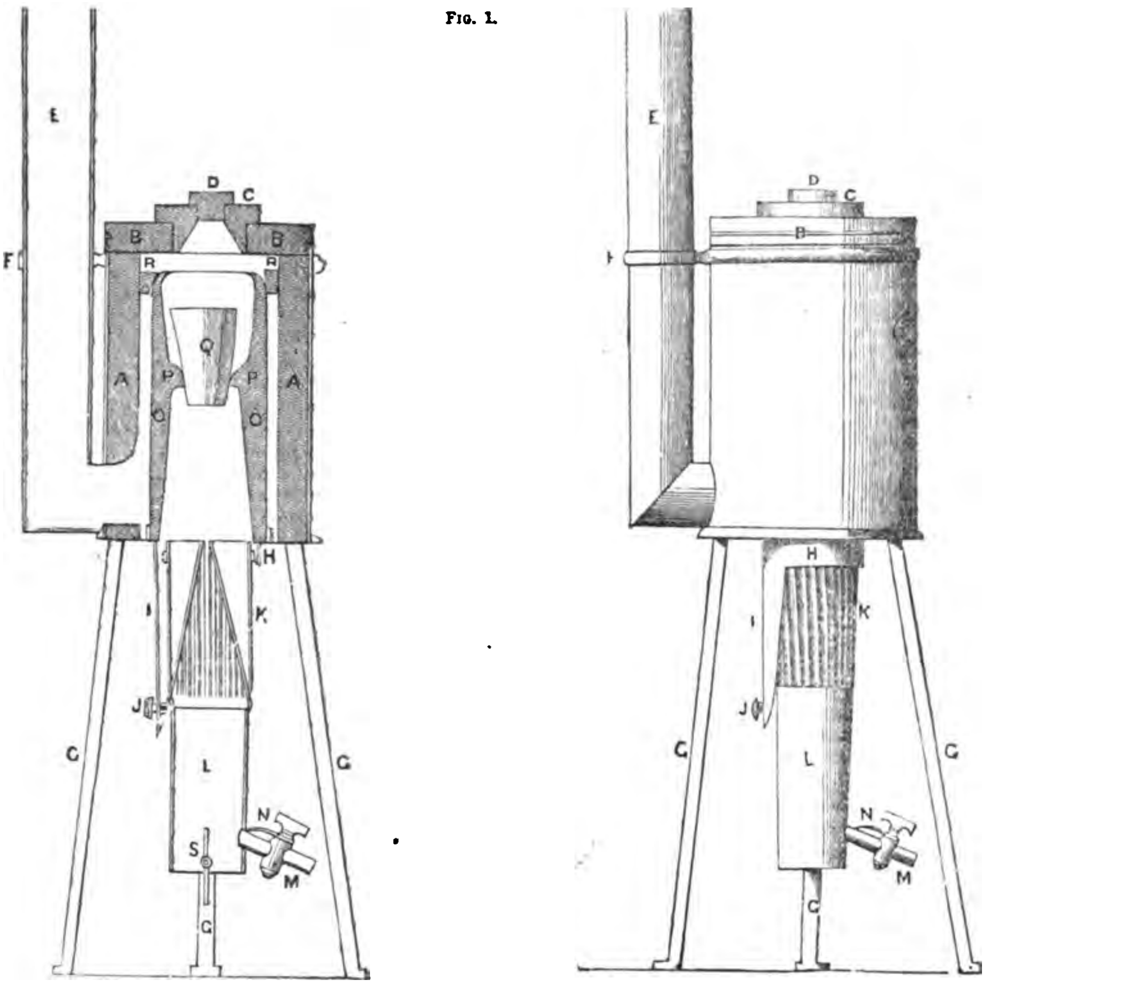
But let us now return to the production of intense heat by the combustion of coal gas. This is effected by burning gas with an excess of air, generally speaking under pressure, so as to bring into contact in a given space of time a large quantity of gases, especially an excess of oxygen, with a view of rendering perfect combustion of coal gas. The first instance, to my knowledge, of the perfect combustion of coal gas as a commercial application, was its use in machines for singeing cotton and woollen fabrics, or for the purpose of removing from their surface all loose and useless fibres. One of the most perfect machines which I have yet examined for accomplishing this purpose has been lately introduced to the notice of manufacturers by Joshua Schofield and Sons, of Manchester. The great merit of their machine consists in the fact that by it they can vary either the intensity of the flame or its length, according to the pressure at which the gases in combustion are made to issue from the machine. In fact, they can adapt with such nicety the action of the machine to the nature of the fabrics they have to singe, that it can be applied to the finest fabric, such as cambrics, and to some of the heaviest materials in cotton, such as fustian.

The most remarkable example of the intense heat which can be obtained by the combustion of gases was brought into notice a few years since by that distinguished chemist, M. H. St. Clair-Deville (the discoverer of aluminium), by which he succeeded not only in melting several metals which, until his experiments, had resisted

* From the Journal of the Society of Arts.

all other modes of effecting their fusion, but in melting in his laboratory as much as 25 lb. of platinum, one of the most refractory metals known, and running it into one solid ingot. In 1862 the well-known metallurgists, Messrs. Johnson and Matthey, invited to their works a large circle of the most scientific men of Europe, who were attending the Exhibition as jurors, to witness the fusion of 220 lb. of platinum, and the running of it into one single solid ingot. This wonderful exploit in the production of heat was effected in a furnace similar in principle to that which had been devised by M. St. Clair-Deville—viz., in a furnace the

FIG. 1.



inner part of which was lined with blocks of quick lime, the only material found by M. Deville to be susceptible of resisting the intense heat which was produced by bringing at the upper part of the furnace a large jet of gas and air intimately mixed, and working under pressure. The flame, in passing from the upper part of the furnace and making its exit at the lower part, produced so great a heat as to melt the above stated quantity of platinum.

The observations of M. Deville soon brought into existence some extremely simple and handy furnaces to effect fusions and assays on a laboratory scale. Some of the best furnaces contrived for that purpose are due to Mr. J. J. Griffin, of Bunhill-row. The principal feature of his furnace is using as a generator for heat a large Bunsen burner, which consists of a hollow tube, at the bottom of which there is an inlet for coal gas, and at a certain height in the tube a number of openings through which the air rushes in to mingle with the gas; both air and gas issue at the top of the tube, and when ignited produce an intense heat. The flame so produced is made to play round a crucible containing the materials to be assayed, and which itself is surrounded by thick earthenware tiles, preventing the heat passing through the furnace from radiating itself in all directions, thus concentrating its action entirely on the little crucible placed in the centre. But the most perfect contrivance of the sort which has yet been brought to the notice of the public is one due to Mr. G. Gore, F.R.S. The following is the description of Mr. Gore's gas furnace:—A is a cylinder of fire-clay, about 9 inches high and 6 inches diameter, open at both ends, and with a hole at the back part near the bottom, to lead into the chimney; it is covered by a movable plate of fire-clay B, with a hole in its centre for the introduction of the crucible or of substances to be melted; this hole is closed by a perforated plug of fire-clay C, for access to the contents of the crucible; and that again is closed by another stopper of fire-clay D. E is a chimney of sheet iron, about 5 or 6 feet high, kept upright by a ring of iron F, attached to the top of the furnace. The fire-clay cylinder is inclosed in a sheet iron casing with a bottom of iron, to which are fixed three iron legs G. An iron tube H, with a prolongation I, supports by means of the screw J, the burner K, and its tube L, which is open at both ends. Gas is supplied to the burner by means of the tap M, which has a small index N, attached to it for assistance in adjusting the gas. Inside the largest cylinder is another fire-clay cylinder or cupola O, with open ends, and with three projections of fire-clay P, for supporting the crucible Q; it is kept steady by means of three clay wedges R: S is an air-valve for closing the bottom of the tube L. The gas burner is a thin metal cylinder, deeply corrugated at its upper end, with the corrugations diminishing to nothing at its lower end, as shown in the engravings. The action of this furnace is as follows:—Gas is admitted to the open tube L, by the tap M; it there mixes with air to form a nearly combustible mixture, which ascends through the burner, and burns in the clay cylinder O, being supplied with the remainder of air necessary to combustion through the tube H, to the outer surface of the flame by means of the spaces between the corrugations. The flame and products of combustion pass up through cylinder O, and then downwards outside of it to the chimney, the point of greatest heat being at Q.

Mr. Gore states that one of his smallest furnaces, consuming

33 feet of coal gas per hour is capable of melting 8 oz. of copper and 6 oz. of cast-iron; that the next sized furnace, consuming about twice the quantity of gas, will melt 40 oz. of copper.

But the most important improvement which has been effected of late years in the production of intense heat by the combustion of the gases generated through the distillation of inferior coals, is that of Mr. C. W. Siemens, F.R.S., of Great George-street. The benefits which are conferred on manufacturers and the public by the furnaces devised by Mr. Siemens cannot be overrated. They are not only economical in their use, but as they enable the manufacturer to use an inferior class of fuel to generate the heat required, they must undeniably be of great advantage; and to the public in general they will be a great boon, as they do away with the nuisance attached to all manufacturing districts, in the dark black smoke escaping from chimneys, polluting the atmosphere, and rendering it so disagreeable to those who are compelled by their occupations to live within reach of its influence.

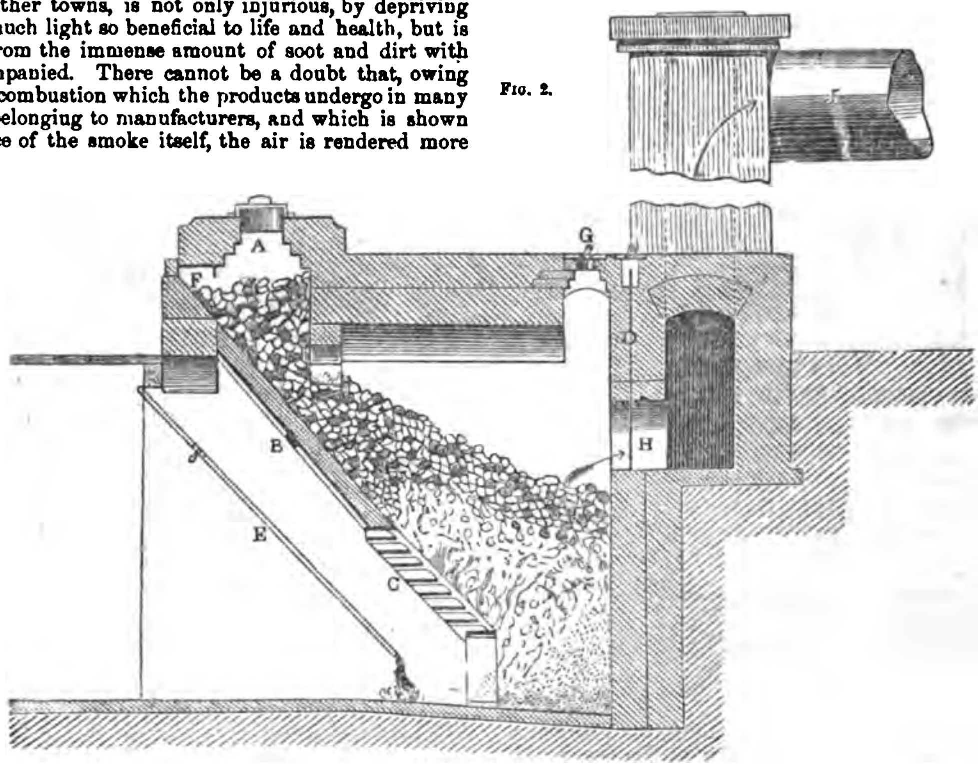
I may state, *en passant*, that the large amount of black smoke which floats in the atmosphere of Manchester, Sheffield, Birmingham, and other towns, is not only injurious, by depriving those places of much light so beneficial to life and health, but is also a nuisance from the immense amount of soot and dirt with which it is accompanied. There cannot be a doubt that, owing to the imperfect combustion which the products undergo in many of the furnaces belonging to manufacturers, and which is shown by the appearance of the smoke itself, the air is rendered more unwholesome than it would be if the products that escape had undergone perfect combustion, because volatile matters escape which are known to have a most destructive action on health and vegetation. The improved state of the public squares in London, and especially of those which are on the banks of the Thames, can be witnessed by all who have observed their condition since the consumption of smoke has been made compulsory in London and its suburbs.

Mr. Siemens's furnaces, I am happy to say, are not in a state of mere experiment, but they have received the sanction of a great number of manufacturers, and especially of those who little expected that the necessary heat for their operations could be obtained without interfering with their manufacture, in the carrying out of which they thought the production of smoke could not be prevented. Thus we find Mr. Siemens's furnaces employed with great success and economy in glass works, in potteries, and in iron forges—works which used to be a nuisance to their neighbours, by the large volumes of black smoke which they were constantly emitting from their chimneys.

Before describing Mr. Siemens's furnace, it is necessary that I should state that, in the ordinary furnaces only about 25 per cent. of the heating power of the fuel is rendered available in carrying out the manufacturing operations. This is due to imperfect combustion, and to the fact that only the heat of combustion exceeding that of the body treated is utilized; the remainder of the heat, in many instances, by far the greater proportion of the whole, being allowed to escape uselessly up the chimney.

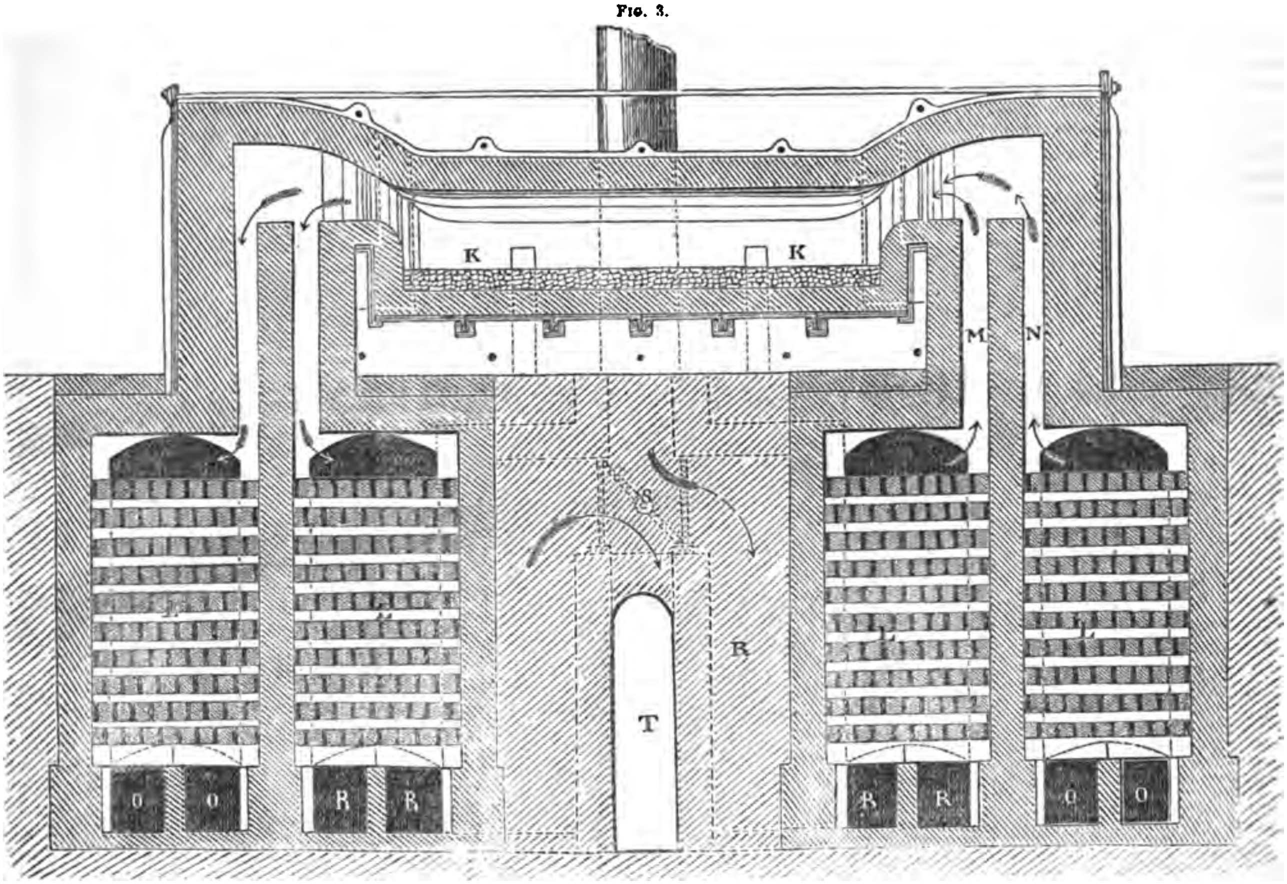
I shall now give a description of one of M. Siemens's furnaces. The gas producer and furnace are quite distinct, and may be placed at any convenient distance from each other. The gas producer is shown in Fig. 2. The fuel is supplied at intervals of about two hours through the covered openings A, and descends gradually on the inclined plane B, which is set at an inclination to suit the kind of fuel used. The upper portion of the incline B, is made solid, being formed of iron plates covered with firebrick, but the lower portion C, is an open grate formed of horizontal flat steps. The opening under the lower step is made larger than the others, to enable clinkers to be withdrawn. The small stoppered holes FF, at the front, and GG, at the top of the producer, are provided to allow of putting in an iron bar occasionally, to break up the mass of fuel and detach clinkers from the side walls. Each producer is capable of converting daily about two tons of fuel into a combustible gas, which passes off through the opening H, into the main gas flue leading to the furnaces.

FIG. 2.



The action of the gas producer in working is as follows:—The fuel descending slowly on the inclined plane B, becomes heated, and parts with its volatile constituents, the hydro-carbon gases, water, ammonia, and a small proportion of carbonic acid, which are the same as would be evolved from it in a gas retort. There now remains from 60 to 70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the current of air slowly entering through the grate C; producing regular combustion immediately upon the grate; but the carbonic acid (an incombustible gas) thus produced, having to pass slowly through a layer of incandescent fuel from 2 to 3 feet thick, takes up another equivalent of carbon, and is thus transformed into carbonic oxide (an inflammable gas) which passes off with the other combustible gases to the furnaces. For every cubic foot of carbonic oxide thus produced, taking the atmosphere to consist of one-fifth part by volume of oxygen and four-fifths of nitrogen, two cubic feet of incombustible nitrogen pass also through the grate, tending greatly to diminish the richness or heating power of the gas. Not all the carbonaceous portion of the fuel is, however, volatilized on such disadvantageous terms: for water is brought to the foot of the grate by the pipe E, which, absorbing the spare heat from the fire, is converted into steam, and each cubic foot of steam in traversing the layer of from 2 to 3 feet of incandescent fuel is decomposed into a mixture consisting of one cubic foot of hydrogen, and nearly an equal volume of carbonic oxide, with a variable small proportion of carbonic acid. Thus one cubic foot of steam yields as much inflammable gas as five cubic feet of atmospheric air; but the one operation is dependent upon the other, inasmuch as the passage of air through the fire is attended with the generation of heat, whereas the production of the water gases, as well as the evolution of the hydro-carbons, is carried on at the expense of heat. The generation of steam from the water, being dependent on the amount of heat in the fire, regulates itself naturally to the requirements; and the total production of combustible gases varies with the admission of air, and since the admission of air into the grate depends in its turn upon the withdrawal of the gases evolved in the producer, the production of the combustible gases is entirely regulated by the demand for them.

Fig. 3.



The gas made in these producers has been frequently carefully analysed, and the average constituents of 100 parts have been found as follows:—

Carbonic acid	4·1
Oxygen	0·4
Carbonic oxide	23·7
Carburetted hydrogen	2·2
Hydrogen	8·0
Nitrogen	61·5
	99·9

The furnaces are applicable for all purposes where intense heat is required, such as for glass houses, puddling, heating iron and steel, iron melting for foundry purposes, steel melting, muffles, and copper smelting. In all applications the furnaces are of the same construction in principle, the arrangements only varying with the different operations to be carried on in the heating chamber. The heating furnace has been selected for illustration in Fig. 3. Underneath the heating chamber K, are placed transversely the four regenerators L L L L, which are chambers filled with fire-bricks built up with spaces between them. The regenerators work in pairs, the two under the right-hand end of the furnace communicating with that end of the heating chamber, while the other two communicate with the opposite end. The gas passes from the main gas flue through the reversing valve S, into the flues RR, at the bottom of one of the regenerators L, up through which it passes to the port M. Air is also admitted through a reversing valve at the back of S (not shown in the figure), thence into the flues OO, up through the second regenerator L, to the port N, where it meets with the gas, mingles with it, and produces an intense and uniform flame, which distributes itself all over the heating chamber K. The products of combustion, together with the excess of waste heat of the furnace, instead of being passed, as in ordinary furnaces, up the stack, and either entirely thrown away or only partially utilized, are carried down into the other pair of regenerators, where they are deprived of their heat, and thence proceed through the reversing valves to the chimney by the flue T.

When one pair of regenerators has become considerably heated by the passage of the hot products of combustion for some time, and the opposite pair correspondingly cooled by the upward passage of the cold gas and air, the valves are reversed, and the currents of gas and air then pass upwards through the regenerators last heated, whereas the products of combustion pass through those opposite. The process of reversing is repeated at fixed intervals, generally every half hour, so that two of the regenerators are always being cooled by the gas and air taking up the deposited heat and carrying it back to the furnace, and two always being heated by the passage of the hot products of combustion passing down to the chimney, and depositing their heat on their way there. The flame in the heating chamber is uniform throughout, and perfectly free from all extraneous matter. Its chemical nature is also perfectly under command by means of gas and air regulating valves (not shown in the engravings), so that the most delicate operations can be carried on with great uniformity. The gas and air reach the heating chamber (after passing through the regenerators) at nearly the heat of that chamber itself, and in burning, in addition to the temperature due to their mutual chemical action, is added that they have taken up in passing through the regenerators, so that an intensity of heat is obtained, which, unless moderated on purpose, would fuze furnace and all exposed to its action.

The products of combustion are so completely deprived of the heat they brought out of the heating chamber K, by passing among the regenerator bricks, that the heat in the chimney-flue is seldom sufficient to singe wood; the economy is therefore due to the fact that little or no heat is thrown away up the chimney, as in the ordinary furnaces, and also to the perfect combustion of the fuel, which is evidenced by the total absence of smoke from the stack; whereas in the common furnaces the combustion is so imperfect, that clouds of powdered carbon, in the form of smoke, envelope all manufacturing towns, and gases are allowed to escape with two-thirds of their heating power undeveloped. The saving of fuel in these furnaces, as compared to the ordinary kind, ranges between 40 and 60 per cent. in weight, according to the fuel used. In many instances an additional saving can be made in the cost of the fuel by using inferior qualities, such as coal and coke dust, lignite, and peat. The intensity of the heat, purity of the flame, and the absence of cutting draughts in the heating chamber, is of great advantage for all metallurgical operations, tending greatly to improve the quality of the produce, and occasioning a saving of about 5 per cent. in the waste of the metal treated in puddling and iron re-heating furnaces, &c. The peculiarities and advantages of these furnaces are, that gas fuel alone is employed, that perfect and entire combustion is obtained, and that the heat, which is usually allowed to escape up the chimney, is here stored up to be afterwards brought back to the furnaces.

Whilst on the question of the combustion of coals and of smoke, I would draw your attention to a clever invention by Mr. Snook, of Manchester, which he calls an "Invigorator." The invention may briefly be described as an apparatus placed within the semi-circle forming the upper portion of an ordinary register fire-grate, formed entirely of cast-iron, and so constructed as to be readily applied to all existing grates known as of the register form. In experiments which have been made, it has been proved that after lighting the fire (the whole of the apparatus being closed so as to act as a blower), a brisk bright fire is produced in about four minutes. A large concave elliptical plate immediately over the grate bars, suspended on end pivots, is tilted over to an angle of about 70 degrees, when it is seen that the back or concave portion of the plate acts as a bright reflector, throwing out the heat rays into the room, instead of allowing them to pass up the chimney. Two horizontal plate doors, or louvres, above the reflector, are next opened, when the draught is found to be reduced to the smallest amount compatible with the continuance of combustion in the grate. The heat thrown out from the fire is considerable, and the fire itself forms a pleasant object to look at, having a warm red glow, without either flame or smoke proceeding from it.

The next invention I wish to refer to is one which, like that of Mr. Siemens, is calculated to render marked service to society. It is the production of motive power through the combustion of coal gas, and you will I hope appreciate the discovery due to Mr. Lenoir, if you will call back to memory the efforts which have been made for the last twenty or thirty years, to generate power by employing the expansion which air or other gases undergo under the influence of heat as a substitute for steam—the long promised success and the unfortunate failures of Ericsson. What especially recommends the engines of M. Lenoir is their safety, for there is no danger of explosion; their cleanliness, for they require no fuel; their simplicity, which enables those who employ them to use them in any room, at any height, and at any spot where motive power may be required, for they have only to erect a little engine of one or two horse power, and, whenever they require to use it, all they have to do is simply to bring into contact two poles of a battery, when the fluid so generated will traverse space, and convey motive power to the gas engine. Lastly, these engines are extremely economical in their working, for they consume only 70 feet of gas per horsepower per hour; and assuming that 1000 feet of gas is worth 4*s.* 6*d.*, the cost of working an engine of one horse power will be about 4*d.* per hour. M. Lenoir's engine is very similar to the ordinary steam-engine, having a cylinder, piston, crank-shaft, and fly-wheel. The following proportions of gas are admitted in the cylinder:—One volume of coal gas mixed with twelve volumes of atmospheric air. This mixture is ignited by the electrical spark from a battery connected by wires at each end of the cylinder. The connection being made and broken by the rotatory action of the crank-shank, the expansive force necessary to move the piston of the engine is produced by the ignition of the gas, which not only produces steam and carbonic acid by their combustion, but by the heat generated increases their volume to a sufficient extent to force the piston to travel backwards and forwards, thus producing motion. The engine once fixed, the battery charged, and the gas turned on, it is ready for action, and as soon as the work required is completed, the gas is shut off, the engine stops, and the expense ceases.

The facility for employing Lenoir's engine in countries where coal is not easily attainable has been increased by substituting for coal gas a mixture of oxide of carbon and hydrogen, which can easily be procured on a commercial scale at a small cost, by passing steam over heated charcoal, the water being decomposed, its hydrogen being liberated, and its oxygen combining with the carbon itself produces oxide of carbon, and the mixture of these gases is a cheap and good substitute for coal gas. Consequently M. Lenoir's engines can be employed with great advantage in our British colonies and in South America.

I shall now call attention to an interesting and valuable invention of one of the most learned and eminent chemists of England, Dr. J. Stenhouse, F.R.S., who has devised quite a new method of waterproofing vegetable and animal tissues and fabrics. Previously to his discovery, the modes of waterproofing consisted in using bees'-wax and various kinds of drying oils, such as linseed, the siccation of which is enhanced by boiling them with peroxides of lead or manganese. Further, you are all aware of the extensive use which has been made of caoutchouc and gutta-percha for waterproofing purposes. Dr. Stenhouse's waterproofing material is a white solid substance, having no odour, undergoing no change through the action of the atmosphere, and which has acquired of late great popularity, by the application which has been made of it as an illuminating and lubricating agent—I mean paraffin, the discovery of which, in a commercial point of view, and its introduction into public notice, are due to Mr. James Young, of Bathgate, near Glasgow, who has now established one of the largest manufactories in the world for the production of this article, notwithstanding it was considered a commercial novelty in 1852. Dr. Stenhouse found that if he employed pure paraffin for waterproofing, owing to its tendency to crystallize it would not adhere sufficiently to fabrics. He, therefore, conceived the happy idea of adding to it a few per cent. of linseed oil, which overcame the defects presented when paraffin was employed alone, effecting a better adhesion between the waterproofing material and the textile fabrics, and rendering leathers more flexible. Dr. Stenhouse melts together paraffin oil with a few per cent. of linseed as above stated. He runs the whole into cakes; and, in order to apply this waterproofing agent, he heats the cake, and rubs the materials over with it, or spreads the melted mixture over the fabric by means of a brush. His process is applied with great advantage by Messrs. Silver and Co., to the waterproofing of soldiers' tents, and other materials of that class, to the great comfort of the soldiers, for, without increasing the weight of their tents, it renders them impermeable, and protects the men from rain and its attendant discomfort and danger. Another most useful application of Dr. Stenhouse's waterproofing material is the rendering of leather impermeable; by examining the specimens you will immediately see the immense advantage that cavalry will derive from having their saddles rubbed over with this preparation, as it renders the leather incapable of absorbing moisture, and enables the soldier to mount his horse after heavy rain with as much comfort as if it had remained under shelter. It also renders the soles of shoes quite impermeable, and at the same time communicates to them great flexibility, so that the boots of navvies, and other similar articles, are rendered far more useful and durable, as we all know that the constant wetting and drying of leather expedites in a marked manner its decay. There is one more application of Dr. Stenhouse's waterproofing to which I should wish to call your special attention, as it is of interest to the manufacturers of Manchester and Lancashire generally. In those districts large quantities of what is called waterproofing materials are used in packing the goods, and preserving them from external wet or injury. Many of these materials are made by covering a coarse calico fabric with a coating of boiled linseed oil, but this class of packing is very imperfect, and loses its strength rapidly, especially in hot climates, owing to the fact that the boiled oil absorbs oxygen and carries it on to the fibre, oxidizing it, and thereby soon destroying its tenacity. By appying Dr. Stenhouse's process to the fabric previously to the drying oil, not only is great impermeability attained, but the fibre, being saturated with paraffin, is preserved from the subsequent oxidation which it would undergo under the influence of the atmosphere in the presence of the boiled oil alone.

I should have wished to have dwelt at some length on the interesting application which has been made of late years, especially on the Continent, of another coal product, which, like most of those whose origin is due to coal, has received many valuable and beautiful applications. The one I now refer to is called bisulphide of carbon, and is applied with great success not only to the extraction of fatty matters from various seeds and fruits, such as olive, linseed, &c., but in Algiers for extracting from flowers various essential oils, commonly called perfumes, such as essence of roses, lavender, jasmine, &c. I would mention also the useful application which bisulphide of carbon receives in the hands of Messrs. Allbright and Co. of Birmingham, in separating the common phosphorus from the red or amorphous phosphorus, now applied to the manufacture of chemical matches.

I cannot conclude my remarks respecting coal products, without stating the fact that, since 1862, many beautiful and valuable discoveries have been made in connection with coal-tar colours. Dr. A. W. Hoffman has succeeded in obtaining some magnificient purples, by a process as curious as it is highly scientific, and such as might be expected from so talented a chemist. Since then a splendid green colour, called verdine, and which has the curious property of retaining that colour in artificial light, yea more than that—of increasing in beauty in the presence of that light—has been discovered by M. Eusebe. A beautiful fast black, easily applicable to the art of calico printing, has also been devised; and lastly, in the hands of Messrs. Simpson, Maule, and Nicholson, the well-known colour called magenta, and a beautiful blue called opal, have not only been much increased in beauty, but their cost of production has been materially reduced. In fact, at the present day, every shade of colour is produced from coal tar products; but the subject is too vast for me to attempt now to enter into details as to their mode of production and application.

I must, though with regret, leave the interesting subjects which have reference to coal and its products, and pass to another class of manufacture. The first of these has reference to the *refining of sugar*, and among the several improvements which have been effected in this branch of manufacture during the last few years none is more important in its general bearing than that recently brought to the notice of the public by Mr. Alfred Fryer, of the well-known firm of Fryer, Benson, and Foster, of Manchester. This gentleman has published some valuable information on the composition of the sugar-cane juice, and the alterations it undergoes under the influence of heat and atmospheric air, and has conferred on the colonies a great boon by inventing an apparatus which will effect a great saving in obtaining sugars. Mr. Fryer's experiments on the cane-juice teach us that, instead of only extracting 49 per cent. of the juice, as is usually the case when the canes are worked by the old system, 61 per cent. can be obtained with a good steam engine having 24-inch rollers; and by pressing the megass a second time through the rollers as much as 70 per cent. can be obtained; and Mr. Fryer does not doubt that even 80 per cent. may be reached, if more attention is paid to the pressing of the canes through the rollers. Mr. Fryer has also published some interesting facts on the action of the oxygen of the atmosphere on cane-juice. Thus he has observed that the juice rapidly darkens, and that this increase of colouration is not only an indication that the juice is undergoing deterioration, but that no amount of defacation will subsequently remove this colouration. He has further noticed that cane-juice rapidly becomes acid, and the acidity increases also in a very rapid manner. He gives an instance—a pattern of too many others—where the juice, after expression, flowed down a spout 250 feet in length, from the mill to the boiling-house, occupying in its descent about half-a-minute. The amount of acidity increased from 100 to 253, and the colour deepened fourfold.

Mr. Fryer has also published some very interesting facts on the influence of heat on the cane sugar, and I here extract from a paper of his the following facts:— "We now come to the boiling. All heat above 140° is capable of exerting an injurious effect. As regards the time, this effect is proportionate to the duration of the heat; the continuance of any syrup for two hours at any given temperature would cause just double the mischief which would be produced by its continuance at the same temperature for an hour. But as regards the heat, the mischief increases about as the square of the difference from 140°, the highest innocuous temperature. So at 160°, during any given time a certain degree of mischief would be done. To keep the same syrup for the same time at the heat of 180° would give [illegible] times the mischief; at 200°, nine times; the difference of 180° from 140° being twice as great as that of 160°, and that of 200° being three times as great."

This mischief consists partly in the change of colour, partly in the change of a quantity of cane sugar or sucrose into fructose. Both these kinds of sugar are present in all neutral saccharine solutions. Sucrose is the ordinary crystallised cane sugar; fructose exists more especially in some kinds of fruit, such as grapes, gooseberries, cherries, oranges, &c., which refuse to form well-defined crystals. Further, I should remark that under the influence of heat, as just stated, cane sugar or sucrose is converted into grape sugar or fructose, and that the presence of fructose interferes in a most extraordinary manner by preventing the free crystallisation of sucrose. Thus, for example, every particle of fructose in a mixed solution detains from crystallisation its own weight of pure sugar. In fact, it would be impossible, after mixing equal weights of loaf sugar and fructose in a solution to recover the former in a crystalline state. The change produced by the atmosphere alone, without the action of heat, shows the necessity of proceeding instantly to raise the temperature to the boiling point, and the concentration should be continued without loss of time. The temperature should not, however, be raised beyond the lowest effectual heat.

From the further end of the cylinder a pasty mass is discharged, and, in cooling, it hardens into a non-crystalline homogeneous substance, likely to be long known as Fryer's "concrete." Its material is simply cane-juice deprived of its vegetable albumen and water, and, not being contaminated by molasses or caramel, is admirably fitted for the operations of the refiner, and will, therefore, command his attention. This process is easy to conduct; the apparatus is simple and self-acting, not liable to derangement; it performs a large amount of work, and therefore proves a material saving to the sugar producer. I cannot conclude my remarks on Mr. Fryer's invention, as applicable to the colonies, better than by repeating here the words expressed by the Governor of Antigua, who said, "I believe firmly that you have opened a new era of prosperity to our colonies, and heartily wish you abundant success in the course on which you have entered." As to the advantages which a sugar refiner in this country will derive from employing Mr. Fryer's "concrete," instead of having to refine the molasses and coarse sugars usually imported into this country, they are so obvious that it would be really a loss of time to enlarge upon them. The saving to the refiner in having nearly pure sugar to operate upon, and not having to contend with the removal of colour, converted sugar, caramel, and other impurities, will at once convince you of the support and approbation the article will receive from the sugar refiner.

If, at the commencement of this lecture, I drew attention to the value of intense heat produced at a small cost, so as to enable our manufacturers to carry on their various processes, it now becomes my duty to inform you that of late years the *cheap production and application of low temperatures* has become a necessity, especially since organic products have been manufactured on an extensive scale. Three different machines for obtaining these low temperatures have been brought to public notice—viz. First, that of Mr. Kirk, who has applied in a beautiful manner some of the physical laws discovered by Dr. J. P. Joule and Prof. W. Thomson, in their researches on the mechanical theory of heat. Thus, Mr. Kirk succeeds in producing a low temperature by condensing under high pressure atmospheric air, which, on being allowed to resume its primitive volume produces cold, for the compressed air cannot resume its primitive volume without the essential element for its expansion, namely, heat; and if the apparatus is properly contrived, which is the case in that of Mr. Kirk's, the heat necessary for the expansion of the compressed air is supplied to it by the body whose temperature is to be lowered. Although the construction of this machine is exceedingly costly, still it has been employed at Mr. James Young's works at Bathgate with great success, for the cooling of paraffin oil, to extract from it the solid paraffin which it contains. The second apparatus is that of Messrs. Harrison and Co., of London, who employ ether as the medium for producing low temperatures. The third is that of M. Carré, in my opinion the cheapest and most practicable apparatus yet invented for the purpose, the more so that it is applicable for household as well as for manufacturing purposes. Although I, like many of you, have witnessed the production of ice by it at the late Exhibition, still I was not prepared to learn that it could be applied with economy to the extraction of some of the salts existing in sea-water. Still such is the fact. M. Ballard, a well-known French chemist, after many years' study and labour, succeeded in extracting from sea-water two products, which play a most important part in most of our large chemical works—viz. sulphate of soda and chloride of potassium. To produce the first, under ordinary circumstances, extensive works are required, such as are found at St. Helen's, and Newcastle-upon-Tyne, where thousands of tons of common salt are acted on by vitriol, which gives rise to muriatic acid and sulphate of soda. As to the salts of potash, the French as well as ourselves are depend nt for it upon the forests of Russia, and the native forest of Canada. By M. Ballard's discovery, France will free itself from a dependence upon foreign supplies for the potashes she may require, as well as the sulphur, and will also do away with the public nuisance, namely, the conversion of common salt into sulphate of soda. Without entering here into details, let me state that M. Ballard operates as follows:—In the early part of the spring season, considerable quantities of sea-water from the Mediterranean are run into large shallow reservoirs. In the summer season the water evaporates, a certain proportion of common salt separates, and the concentrated water is stored in other reservoirs until winter, when it is again allowed to flow back into the shallow reservoirs, where it yields, during a cold night, thousands of tons of sulphate of soda. The mother liquors from which the sulphate of soda has separated are allowed to flow into Carré's apparatus, where they are subjected to a comparatively intense cold, and yield large quantities of a double chloride of magnesium and potassium, which, on being subjected to heat in a furnace, gives hydro-chloric acid, magnesia, and

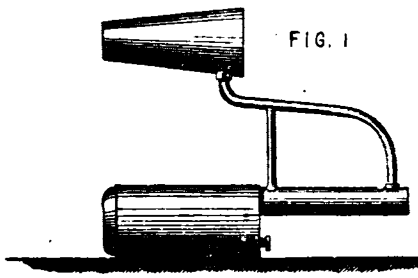


FIG. 1

chloride of potassium. This application of Carré's apparatus, in this instance, shows the simplicity and practicability of it. It is based on rather a different principle to those of Kirk and Harrison. To obtain a low temperature he applies heat to a vessel which contains a saturated solution of ammoniacal gas. This drives off the gas, which is made to pass into a vessel surrounded with cold water, when it liquifies itself by its own pressure. If then the heat be removed from under the solution, its temperature will gradually fall, and it will become again susceptible of re-absorbing the ammoniacal gas, thus facilitating its evaporation from the vessel in which it has condensed, and as it is neces-

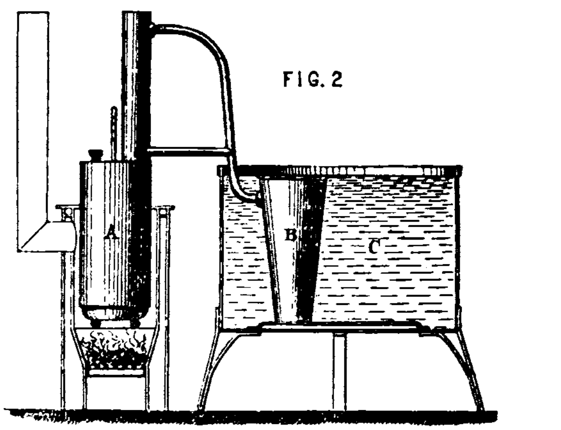
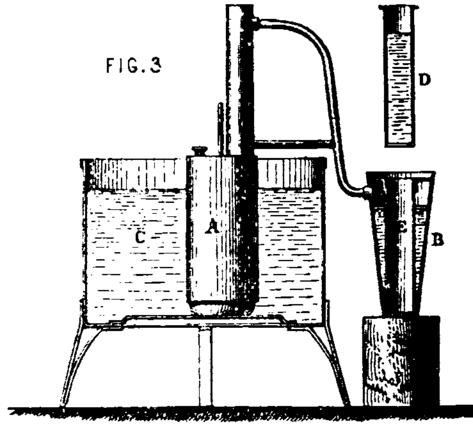


FIG. 2

sary for the passage of the liquified ammoniacal gas into its gaseous form that it should absorb the heat from the surrounding medium, let it be water or any other fluids, their temperature will gradually decrease. The following diagrams will explain better the working of this invention:—

Before each operation incline the apparatus horizontally, and maintain it about ten minutes in the position represented in Fig. 1. Place the boiler A (Fig. 2) in the furnace, and the refrigerator B, in a bucket filled with cold water, so that the summit of

FIG. 3



the refrigerator be covered with two or three inches of water. A small quantity of oil is poured into the tube which is placed in the upper part of the boiler, in which also a thermometer is placed. The apparatus is heated moderately until it reaches 266°. The apparatus is then removed from the fire, and the boiler is placed in the bucket of cold water (Fig. 3.) The hole of the refrigerator being stopped with a cork, and the tin vessel surrounded with alcohol, having previously nearly filled it with water, the congelation takes place by the evaporation of the liquid ammonia in the condenser.

I cannot end without calling attention to a very ingenious mode, devised by M. Pelon, for *warming railway carriages* during cold weather. You are too well acquainted with the present clumsy and expensive method now in use to require any description from me. The only remark I shall make upon it is that it is the boon of those who are in least need of it—namely, first-class passengers; whilst those of the second and third classes have not that luxury supplied to them. I shall not attempt to describe the various methods which have been proposed as substitutes for the one at present in use, but shall at once state that M. Pelon's method is based on the conversion of force into heat, the heat in this case being generated by friction. All those persons who were fortunate enough to visit the French Exhibition in 1855 must have been struck with a machine invented by Messrs. Mayer and Beaumont, which generated enough heat to convert water into steam, and thus obtain a motive power; and this was effected without fuel or electricity, but by mere frictional heat, which they obtained by causing a wooden mandril surrounded with tow to revolve with great rapidity inside a copper cylinder, which itself was surrounded with a small quantity of water. The great merit of the invention of these gentlemen, and which drew upon them the special attention of the Emperor, was that neither the towed mandril, nor the copper cylinder were materially injured or deteriorated after many day's working. This important end was attained by them by allowing a gentle flow of oil to run constantly through the cylinder, thus preventing immediate contact between the towed mandril and the copper cylinder. In fact, the frictional heat was produced through the friction which took place between the particles of oil themselves, preventing thereby all wear and tear. Notwithstanding the ingenuity displayed in this invention, still as a means of obtaining motive power it was useless, for more force was required to generate an amount of heat than could be yielded by the friction of the particles of oil. But in the application which M. Pelon has made of this invention to the heating of railway carriages the motive power required to generate the heat being produced without cost to railway companies, as it is caused by the very act of the travelling of the carriages themselves, the cause which accounted for the failure of the principle as a practical mechanical application, namely, the production of the force required to work it, is overcome. M. Pelon proposes to fix one of Messrs. Mayer and Beaumont's mandrils under each railway carriage compartment, and to convey the heat produced by the revolution of the towed mandril to the compartment itself by means of metallic conducting surfaces, which in their turn will heat the atmosphere of the compartments. We shall, I am happy to say, within a year or two know if M. Pelon's invention will be capable of general adaptation, as it is now being practically tested on one or two of the French railways.

SUGGESTIONS FOR IMPROVEMENTS IN BLOCKS FOR LOWERING SHIPS' BOATS.*

By L. G. Fawcut.

Many accidents happen in lowering boats at sea from a ship's side, owing to the difficulty of unhooking the lower blocks of boats' tackle when there is any weight or strain on the hook. One of these suggested improvements is the replacing the hook of the ordinary single block by a cross pin, formed by an eyebolt falling from a joint on the shell, and fitting into a cup or socket with an opening on one side, on the end of another bar. These move between the shells of the block below the sheave, and the cup or socket is turned by a lever, like the handle of a vice screw. As this lever is moved it turns up or down the opening on the side of the cup, and so secures or disengages the end of the bar, which falls by the pressure of the weight suspended.

The end of the lever can be secured from the effect of blows, or accidental catching against anything with which it may come in contact, by being placed in an eye, with an opening on one side formed on the head of the sheave pin, and secured there by a keep-ring turning round to the closed side of the eye.

The second arrangement suggested is an improvement of the principle of the towing hook used by the tug steamboats on the Tyne. This consists of a trip hook working on cross bearings, on one of which a lever is fitted like a crank, between the shell and binding of the block. An elbow-shaped lever with a bossed hole near the elbow works round the sheave-pin between the shell and strap, which are kept apart on one side, to leave a space between for this purpose. One end of this bent lever has a catch to secure the end of the crank lever which moves with the hook; and when the catch is raised, by pulling upwards that end of the elbow-shaped lever, the hook either disengages itself, or the other end of the elbow-shaped lever forces forward the upper end of the hook lever, and so frees the hook, in case it should be held by any cause, and not give way to the pressure acting on one side of the hook with the bearings on one side of the centre of the block. The movement is also assisted by the expanding curve of the hook. The sides of the openings in the shell form guides, and prevent any dragging on the hook point, which is also rounded off to ensure the slipping.

At the Newcastle meeting of the British Association in 1863, there was exhibited a method of constructing boats, so that several of the same size and shape could be packed together indiscriminately. Some further improvements have been made in the fittings, and have recently been submitted for the consideration of the Lords Commissioners of the Admiralty. They required some plan "to bring the sides of the lower boat together, to enable the thwarts to be freed in the event of warping or alteration of shape, consequent on exposure to a tropical heat." A tapered pin, to fit into iron plates with double and single eyes, placed respectively on the ends of the seats and sides of the boats, was suggested as a remedy, and with a view to prevent these alterations of shape. The following additional strengthenings were suggested:—A strong iron strap was fitted like a timber on the inside of the boat where the centre of the seat-end met the side; this strap had a solid eye formed on it to fit a corresponding double or single eye formed at the end of the plate on the end of the seat, in addition to filling-in pieces between the timbers for the seats to rest on. The top planks were strengthened by strong gunwale pieces on each edge, with strong filling-in pieces between them, placed opposite where the ends of the seats are fitted to; these pieces were fastened to timbers, and were further secured by plates on the outside bolted through to the inside strap. In connection with these were rings and eye bolts, for lifting or securing the boats, as it was considered that the system of lifting boats by the extreme ends, and lashing them down in the middle, aggravated the tendency boats have to expand or drop out.

The above arrangement is available for lifting the boats by the sides, and substituting rigid bars instead of lashings, the bars thus supporting the top sides of the boats instead of pulling them down. It was suggested that new boats previous to completion might be better prepared to stand the effect of change of climate by being seasoned, by gradually heating the inside and lubricating the outside, a coating of lime being applied to remove the lubrication and further season the boats, while they could be firmly secured by strong framing until their tendency to alter their shape was exhausted.

* Read before the British Association.

ON SUGAR-MAKING MACHINERY.*

By Perry F. Nursey.

In an age when knowledge was power of a tyrannical and oppressive character, it was tolerable that a veil of impenetrable mystery should be drawn around the early germinations of science by her bigoted votaries, and that the pursuit of knowledge should be allowed only to the few, while the mass wandered ignorantly on in mingled terror and admiration. But it is not tolerable that in our day any system of practically applied science should be designedly mystified and jealously guarded by a few monopolists, or that in any branch of manufacture a special limitation should be observed, lest perchance a ray of light the more should gleam upon the path of the inquirer in his search for practical knowledge. Nevertheless, that such is the case is the experience of many who have fruitlessly sought for information upon the subject of the present paper. The well-known secresy observed by those engaged in the manufacture both of sugar and sugar machinery has undoubtedly given an advantage to a few engineers whose charges and whose workmanship are not always what they might be if a moderate amount of competition were introduced; but to the many information has been peculiarly inaccessible, owing to the scant and often vague and designedly mystified way in which the mechanical part of the subject is treated in the few articles which have been written upon it, and owing also to the difficulty—nay, impossibility—of obtaining particulars from those who possess them. But the day of crafts and mysteries has wellnigh passed away, and although the sugar faction may be the last to yield to the universal demand for knowledge, yet the time must come when the barriers of their exclusiveness shall be broken down, and the weakness of their strength become apparent; for, after all, the process of sugar manufacture is a very simple matter. To Mr. Burgh is due the credit of having published the first practical treatise on sugar machinery, and this, too, in utter disregard of the susceptibilities of the sugar faction, with which Mr. Burgh—to use one of his favourite expressions—was doubtless "practically acquainted." The author's materials, however, were gathered before Mr. Burgh's work came out, or possibly the present paper would never have appeared. The difficulty experienced by the author in obtaining information upon the subject induced him subsequently to extend his researches, and he has gone with some care into the matter with the view of submitting the results to the society. A greater delay than he anticipated has occurred in the production of the paper, which, however, it is hoped may be found to contain some useful information upon the manufacture of sugar and the machinery employed therein. It is proposed to notice briefly the history of sugar, its varieties and its chemistry, and, at greater length, its manufacture, under which head the various mechanical appliances will be considered, and estimates of machinery will also be given.

The author then proceeded to give a general outline of the history of sugar and its manufacture, from the earliest times. He then enumerated and described the several varieties of sugar. In a third section he noticed the subject from a chemical point of view, after which he observed that the manufacture of sugar from the sugar-cane might be classed under four heads:—1, cultivation of the cane; 2, extraction of the juice; 3, purification of the juice and its concentration; and, 4, its crystallisation or granulation.

I.—*Cultivation of the Cane.*

Cultivators distinguish three great varieties of canes—the Creole, the Batavian, and the Otaheite. The Creole cane is indigenous to India, and was transplanted thence to Sicily, the

* Read before the Society of Engineers.

Canary Isles, the Antilles, South America, and the West Indies. It has dark green leaves, and a thin but very knotty stem. The Batavian or striped cane, which has a dense foliage, and is covered with purple stripes, is a native of Java, where it is chiefly cultivated for the manufacture of rum; it is also met with in some parts of the new world and the West Indies. The Otaheite variety grows most luxuriantly, is the most juicy, and yields the largest product. It is cultivated chiefly in the West Indies and South America; it ripens in ten months, and is hardier than the other varieties.

The sugar-cane being originally a bog plant, requires a moist, nutritive soil, and a hot tropical or sub-tropical climate. It is propagated by slips or pieces of the stem, with buds on them, and about 2 feet long. It arrives at maturity in twelve or sixteen months, according to the temperature; the leaves fall off towards the following season, and the stem acquires a straw-yellow colour. The cane is cut by some planters before the flowering season, but it is more usual to cut it some weeks after. The plantations are so arranged that the various divisions of the field may ripen in succession. The land should be supplied with manure rich in nitrogen, but not containing much saline matter. After the harvest the roots strike again, and produce a fresh crop of canes; but in about six years they require to be removed.

The time for cutting the cane varies with the soil and season, and the different varieties of cane. In a state of maturity the canes are from 6 feet to 15 feet in length, and from $1\frac{1}{2}$ inch to 2 inches in diameter. The usual signs of maturity are a dry, smooth, brittle skin, a heavy cane, a grey pith, and sweet and glutinous juice. Canes should be cut in dry weather, or the juice will be found diluted with an excess of water. When cut they are tied up in bundles, and conveyed to the crushing mill, particular attention being paid that the supply should not exceed the demand, otherwise the cut canes would ferment and spoil.

The sugar-cane grows from pieces or slips of itself, containing germs, and these develop rootlets at the joints, which draw sustenance to the young shoot as it increases. In the course of time the buds in the radicle, or root-joints of the first cane, throw out roots, and form a radicle for a second stem; and in this way, under favourable circumstances, several canes are produced from the parent stock for a period of about six years, and sometimes for several more. They, however, diminish every year in length of joint and circumference, and are inferior in appearance to the original plant; but they yield richer juice, and produce finer sugar. Opinions vary as to the distance canes should be planted from each other, some planters recommending 6 feet, others 8 feet, and others again 10 feet spaces; but the system of wide planting is gradually superseding the old close planting, with great advantage to the cultivator.

One variety of cane much cultivated in Jamaica came from Otaheite. With a favourable soil and good cultivation it grows to a height of 12 feet or 14 feet in the first year, being 6 inches in circumference, and having joints 6 inches apart; they will produce $2\frac{1}{2}$ tons to 3 tons of dry sugar per acre, but a good average is 2 tons per acre. The China cane is very hardy, standing both cold and drought, and with plenty of rain giving out as many as thirty shoots. The Sangalore cane is considered the finest in the straits of Singapore, or, perhaps, in the world. It has been known to produce 7200 lb. of undrained sugar per acre, equal to 5800 lb. of dry sugar for shipping. Dr. Livingstone states that sugar is cultivated in the Shire Valley, as well as in many parts of Africa near the Zambesi, and may be had for as little as one halfpenny per pound.

Dr. Evans gives the products of an acre of canes in Barbadoes as—

Weight of Canes.	Weight of Juice.	Extract.	Extract per 100 lb. of Juice.	Extract per 100 lb. of canes.
30 tons	60,480 lb.	10,886 lb.	18·0	16·20
30 „	47,040 „	8467 „	18·0	12·6
30 „	33,600 „	3500 „	10·0	5·0
30 „	33,600 „	7280 „	21·6	10·8

An acre may be said to yield 30 tons of canes. The following table gives the produce in juice and sugar:—

Juice obtained per cent.	Juice in lbs.	Pounds of Sugar.			Subtract for molasses and skimmings at 12 per cent.			Pounds of dry sugar yielded by 1 acre.		
		At 18 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.
70	47,040	8468	9408	10,348	705	792	862	7076	8616	9485
75	50,400	9092	10,080	11,088	757	840	924	8003	9240	10,164
08	53,760	9676	10,752	11,827	806	896	994	8871	9856	11,173

This supposes the juice to stand at 10 deg. Beaumé; at the same time all the numbers given are above the amount actually obtained in practice, which it is very difficult to ascertain. But a very fair specimen of the yield per acre is 4000 lb. of sugar, and 170 gallons of rum 20 per cent. over proof.

Of the 18 to 22 per cent. of sugar in the cane, it is generally believed that only 8 is obtained crystallised. If only 50 per cent. of the juice is taken from the cane, and 30 still remain in it, it is clear that three-eighths of the sugar are taken away in the megass and burnt as fuel. The value of sugar to the planter cannot be far short of £20 per ton, and he could procure coal at an infinitely lower price. But loss as this seems, it would not be so important if the ashes of the megass were thrown on the soil. The climates which grow sugar grow ligneous fibre rapidly, and it is well to use it for fuel where possible. But the soil should not be deprived of its inorganic constituents.

Our West India sugar manufacture, as a whole, appears to be in an unsatisfactory state, and the depressed condition of our colonies has been referred quite as much to the defective culture of the cane, and the injurious methods of expressing and evaporating the juice, as to political causes. The land has been very imperfectly worked by hand-hoeing, and the expressed canes instead of being returned to the land as manure—for which they are as eminently fitted as they are practically necessary—are used as fuel in evaporating the juice. The cheap rate at which coal can be obtained from Great Britain makes it desirable that this practice should be abandoned, and the cane trash or megass put to its legitimate use. The manufacture has been unaided by the application of those mechanical and chemical means which have so prospered European enterprise, and the unimproving planters have drawn upon themselves those pecuniary difficulties which must result to those who insist upon standing still while others progress. If from beet-root 7 per cent. of refined sugar can be extracted, it is not too much to expect the same skill to produce 10 per cent. or 12 per cent. from the sugar-cane. By improved methods of treatment the planters in Java and Cuba, and in some few instances in our own colonies, are extracting and sending to market 10 per cent. to 12 per cent. of raw sugar from the 100 lb. of canes. This result of the employment of better machinery, and more refined chemical applications, is a striking comment upon the West Indian practice, whereby of the 18 per cent. of sugar contained in the average cane juice, not more than 6 per cent., or one third, is sent to market in the form of crystallised sugar. This loss is accounted for by the fact that of the 90 per cent. of juice contained in the cane, only 50 per cent. or 60 per cent. is expressed, one-third being left in the megass, as before noticed, and used as fuel; by the loss of one-fifth or more of the sugar in the juice by imperfect clarifying, and in skimming; and by the crystallisation of only from one-half to two-thirds of the juice when boiled down and set to cool, the remainder running off as molasses, and although these and the skimmings are fermented and distilled for rum, there is still a considerable loss. In the interior of Java, where fuel is scarce, the molasses is worthless, but in the West Indies it is a marketable article, and may be distilled with profit.

The object of the colonial sugar-boiler is to convert the juice as speedily and with as few operations as possible into raw sugar, hence he has shown but little care for improving upon the old system of manufacture, which is attended by loss at every stage. While science has been actively engaged in perfecting the manufacture of beet-root sugar, she has until lately done comparatively nothing for that of cane sugar; but now that attention has been fairly given to the matter, it is found that much of the beetroot apparatus is fitted for cane sugar.

The means by which a better result is to be attained are, undoubtedly, the use of improved cane mills, whereby 70 per cent., and even 75 per cent., of the juice can be expressed; of improved methods of clarifying,—of charcoal filters before boiling, which supersede skimming of steam and vacuum boilers, by which burning is prevented and rapid concentration is effected,—of centrifugal drainers to dry the sugar speedily and save the molasses,—and of coal or wood as fuel where the megass is insufficient for the purpose.

II.—*Extraction of the Juice.*

The sugar exists in the cells of the cane in a state of solution, and is extracted therefrom by pressure. Like as with other branches of industry, science has of late years stepped in here, and greatly facilitated the process of extraction and manufacture. It may be as well to give here a summary of the processes employed in the preparation of raw sugar. The canes are passed through the mill, and the juice thus extracted from them runs into a tank, whence it is pumped into cisterns for supplying the clarifiers, heated by steam, where it is purified. From thence it is run into bag filters, by which the mechanical impurities are removed. It is then run into charcoal filters, to remove the colouring matter of the juice. The filtered juice is then run off into tanks, and is drawn thence by vacuum into the vacuum-pan, where it is granulated, and from whence it is finally discharged for packing. When the steam clarifiers are not employed, the cane juice is run into a series of pans or "teaches," over open fires. This apparatus is also known as a "battery," and forms another method of purification.

The original crushing apparatus of India was a kind of squeezing mortar, made out of the hollow trunk of a tamarind tree, and worked by a yoke of oxen, the pestle or stamper being a strong beam 18 feet long, and rounded at the bottom, so as to squeeze or crush the canes in the mortar. Mills similar to those used for crushing oil seeds were used—as were also several other forms of apparatus—before rollers were introduced. Stone and iron rollers were first used, with the axes in a vertical position, but the horizontal was soon found to be the more convenient and economical. The importance of a systematic mechanical arrangement appears to have awakened attention during the reign of Charles II., for in 1663 Lord Willoughby and Lawrence Hyde (second son of Edward, Earl of Clarendon, High Chancellor of England) associated themselves with one David de Marcato, an inventor, and obtained a patent for twenty-one years for making and framing sugar mills. In 1691, John Tizack patented an engine for milling sugar canes, &c.; but in this, as in the previous case, it is not specified how the mill should be made. Later on, in 1721, William Harding, a smith, of London, who had been many years in Jamaica, and was skilled in the manufacture of sugar mills, having observed their imperfections, how that they were chiefly made with large wooden cogs cased with iron, endeavoured while abroad to improve their construction, but failed for want of competent workmen. On his return to London he made models of sugar mills, which were approved of by the Royal Society. These mills were fitted with cast-iron rollers and cog wheel gearing, and were worked by water power; from description they appear to be the type of mills of the present day. Some forty-five years later, Yonge and Barclay, ironfounders, of Allhallows-lane, City, applied friction wheels to sugar mills. In 1773, John Fleming, a mill carpenter, proposed an arrangement of windmill sails, which turned a vertical timber shaft shod with iron, and which gave motion to two hard wooden rollers, between which the cane was guided and squeezed. In 1807, H. C. Newman, of St. Christopher, West Indies, designed a mill to be worked by horse-power. He used cog and crown wheels to give motion to three vertical rollers, and the arrangement was considered one which greatly augmented the power and execution of this class of machinery. In 1821, John Collinge, of Lambeth, improved cast iron sugar mills by casting the rollers on wrought-iron shafts, instead of keying them on as previously done. In 1840, James Robinson patented improvements in sugar mills, which consisted in using four rollers, one large one and three smaller ones beneath, placed horizontally, and gearing by cogs into each other. Up to that time three rollers only appear to have been used. He also proposed to use six rollers, which are fed from an endless band passing over the rollers. He cast the rollers and shafts in one piece, cored out to admit steam to facilitate the extraction of the juice from the cane during crushing. He also proposed to tin the interior of vacuum pans, &c. Various other arrangements have been patented, but it is unnecessary here to enumerate, much less to describe them. The foregoing examples give an idea of the progress of the subject during nearly 200 years. The last ten years have seen rapid strides made in improving the make of mills, and the general arrangements of sugar works.

Before proceeding to consider the mills at present in general use, it will be as well to notice Bessemer's cane press, which entirely dispenses with rollers, to the use of which Mr. Bessemer objected on the ground that the time allowed by them for the pressure on the cane was too short to displace all the fluid from the congeries of cells in which it was stored, and that, moreover, the amount of pressure on different parts of the cane is unequal, since the rind and knobs are harder and more woody than the rest of the cane. Mr. Bessemer's press consists of a crank shaft with three throws upon it, an oscillating steam cylinder, and solid pistons on plungers fitting in gun-metal tubes, which are perforated by small holes, the interior orifice of each hole being smaller than the exterior, to prevent choking up. Above the tubes are hoppers, down which the canes pass vertically; and as the plunger makes its stroke in the direction of the crank, the end of the plunger cuts off from the cane a piece equal to the height of the tube, while its further progress forces the newly-cut portion against a mass of already crushed cane, whereby the greater part of the juice is forced out; but as the cane contains solid matter, the plunger, in finishing the stroke, must force the whole mass of crushed cane forwards a distance equal to that occupied by the solid portion of the newly-interposed piece, which movement of the mass displaces at the open end of the tube an equal portion of the mass which occupies it. During the cutting off and pressing of this juice the plunger will have moved forward under the hopper, and a portion of the cane within it will have fallen down within the tube. The reverse motion of the plunger also cuts off a length from it, and forces it against the mass of cane trash, expressing the cane-juice as before. In this way the reciprocating motion of the plunger acts on two pieces of cane at every stroke, and a similar operation also takes place at the same time in as many tubes as may be placed side by side over the cistern. In this cistern is a self-regulating heating apparatus, for raising the juice to the temperature required for defacation within two minutes after its expression. The cane trash is produced in a condition favourable for fuel; it falls upon a carrier, and, after being conveyed through a drying apparatus, is delivered at the furnace door of the evaporating pans. It is stated that the juice obtained by this method is larger in quantity, less coloured, and more free from small broken fragments, than when the pressure is performed by means of rollers. This press, however, has not come into general favour, its adoption being very limited.

Wind has been very much used as a motive power for driving the cane mill, but it is objectionable on account of its irregular velocity, which renders it inferior to any other description of power for crushing. It has been ascertained, by comparing the results from forty-four mills in Guadaloupe, driven by different kinds of power, that with windmills of inferior construction the cane mills produced only 50 per cent. of juice; with the ordinary windmills the yield was 56·4 per cent.; animal power gave 58·5 per cent.; water power averaged 59·3 per cent.; and steam, 61·8 per cent. Recent improvements have, however, brought the yield up to 75 or 80 per cent. Steam power, therefore, is coming into general use for cane mills, and many improvements have been effected in engines specially constructed for this class of work.

The sugar mills generally employed are of three descriptions chiefly—the horizontal roller mill, the vertical roller mill, and the hydraulic press; the latter has however received but very limited patronage. The vertical mill has the advantage of being more easily cleaned than the horizontal, but is less easily fed, and is more costly in construction, than the horizontal three-roller mill, which is the form of construction usually employed. Mills have been constructed with five and with four rollers. In the five-roller mill three are placed below and two above. It is considered that this mill will extract 10 per cent. more juice from the cane than the three-roller one; but the megass is thereby much broken, and a much greater power is required to work the mill. In the four-roller mill, where two rollers are placed above and two below, the driving power is not much greater than that required in the ordinary three-roller mill, and a superior amount of juice is obtained. It is therefore probable that the four-roller mill will gradually supersede those now in general use.

A cane mill of improved construction for ordinary use consists of a bedplate of cast-iron, weighing not less than 2 tons 5 cwt.

It is cast with a concave bottom, to receive the cane juice, and has a delivery cast on the side for discharging the juice into the tank, whence it is pumped to the clarifiers by the pump, which is worked from a crank on the shaft of the upper roll of the mill. Fitting strips are cast on each side, and faced to receive the side frames. The bedplate is bolted down to the foundations with four 3½-inch bolts, passing through the side frames, and held down with plates and keys, and also with four 1½-inch holding-down bolts, 6 ft. 9 in. long. The side frames are of cast-iron, and weigh not less than 36 cwt. each; they are cored through to receive the bolts, and are cast with bosses for adjusting screws, 2½ inches diameter, by which the space between the rolls is regulated. The upper roll is distant from the two lower ones about one-fifth to one-quarter of an inch. The frames are accurately faced at bottom and fitted to the bedplate. They are held down by the bolts, which also hold down the centre caps of the upper roll. Spaces are left in the frames to attach a trash-turner, which is placed between the two lower rolls, and under the top one, to guide the cane between the upper and second lower roll. Openings are left to place the rolls; and cast-iron filling-up pieces are provided, accurately fitted and held in place by diagonal bolts, 2½ inches in diameter. A wrought-iron feeding table, and wrought-iron megass delivery, are provided. The three cast-iron rolls are each 2 ft. 2 in. diameter. Each roll should weigh not less than 35 cwt., and be rough-turned. The two lower rolls are cast with flanges on the outer sides, to prevent the cane-juice spreading beyond the rolls. Each roll is cored 8 inches square through the centre, and is hung with eight keys to the shaft. Wrought-iron rings are shrunk on to the shafts outside the rolls to prevent the keys starting. The shafts are of the best wrought-iron 8 inches square, with 7-inch journals, and have square ends for hanging pinions to connect the rolls. A clutch box is cast on the pinion for connecting to the intermediate shaft. The bearings are of the best gun-metal, accurately bored, and fitted in the side frames with a flange on each side, steel plates are fitted at the back of the bearings to receive the thrust of the adjusting screws, which are passed through spaces in the side frames. Three spur pinions, each 2 ft. 2 in. diameter, 3·14 pitch, and 8 inches broad, are hung, each with eight keys, to the ends of the roller shafts, to connect the rolls for work. The intermediate shaft is of cast-iron, 8½ inches square, 9½ inches square at each end, and is connected to the shaft of the upper roll by a square clutch box, and to the intermediate gearing by another square clutch box. The intermediate gearing consists of a spur pinion 1 ft. 9 in. diameter, 3·14 pitch, 9 inches broad, bored out and fitted to the engine shaft, and makes forty revolutions per minute, and works into a spur wheel which is 7 feet diameter and 9 inches broad, and is hung to the shaft with eight keys. The shaft is of cast-iron, 8½ inches diameter, and the journals are 7 inches diameter by 9 inches long, with collars left on each side. The distance between the insides of bearings should not be less than 4 ft. 4 in. This shaft makes ten revolutions per minute, and runs in plummer blocks, which are fitted with gun metal bearings and are provided with wall plates and holding-down bolts 1½ inch diameter, to fasten them down to the brickwork. The pinion is 1 ft. 9 in. diameter, 3·14 pitch, 9 inches broad, and is hung to a shaft with four keys, and works into a spur wheel which is 7 feet diameter, 9 inches broad, and 3·14 pitch, and has six arms, and is hung to a shaft with eight keys. This shaft is cast-iron, 9 inches diameter; one end is formed 9½ inches square for connection to the mill. This shaft runs in two plummer blocks, which are fitted with turned gun metal bearings, and are provided with wall plates and holding-down bolts. This shaft makes 2½ revolutions per minute, that being the speed at which the rolls are required to revolve. Motion is obtained from the engine, which is high-pressure, and of 16 nominal horse-power, having a fly-wheel 14 feet diameter, weighing 3 tons and making forty revolutions per minute. Steam is supplied from a Cornish boiler, 20 feet long, 6 feet diameter, and 3 feet tube, fitted with pressure gauges, safety valves, whistle valve, damper, &c.

(To be continued.)

Coal in Turkey.—The search for coal, made by order of the Turkish Government in the province of Anatolia, in Turkey in Asia, has resulted in the discovery of a large coal-field at the base of Mount Olympus. The quality is stated to be excellent for steam-boiler purposes, and the supply so abundant that it can be sold at 8s. per ton.

THE RELATIVE ADVANTAGES OF THE INCH AND METRE AS THE STANDARD UNIT OF DECIMAL MEASURE.

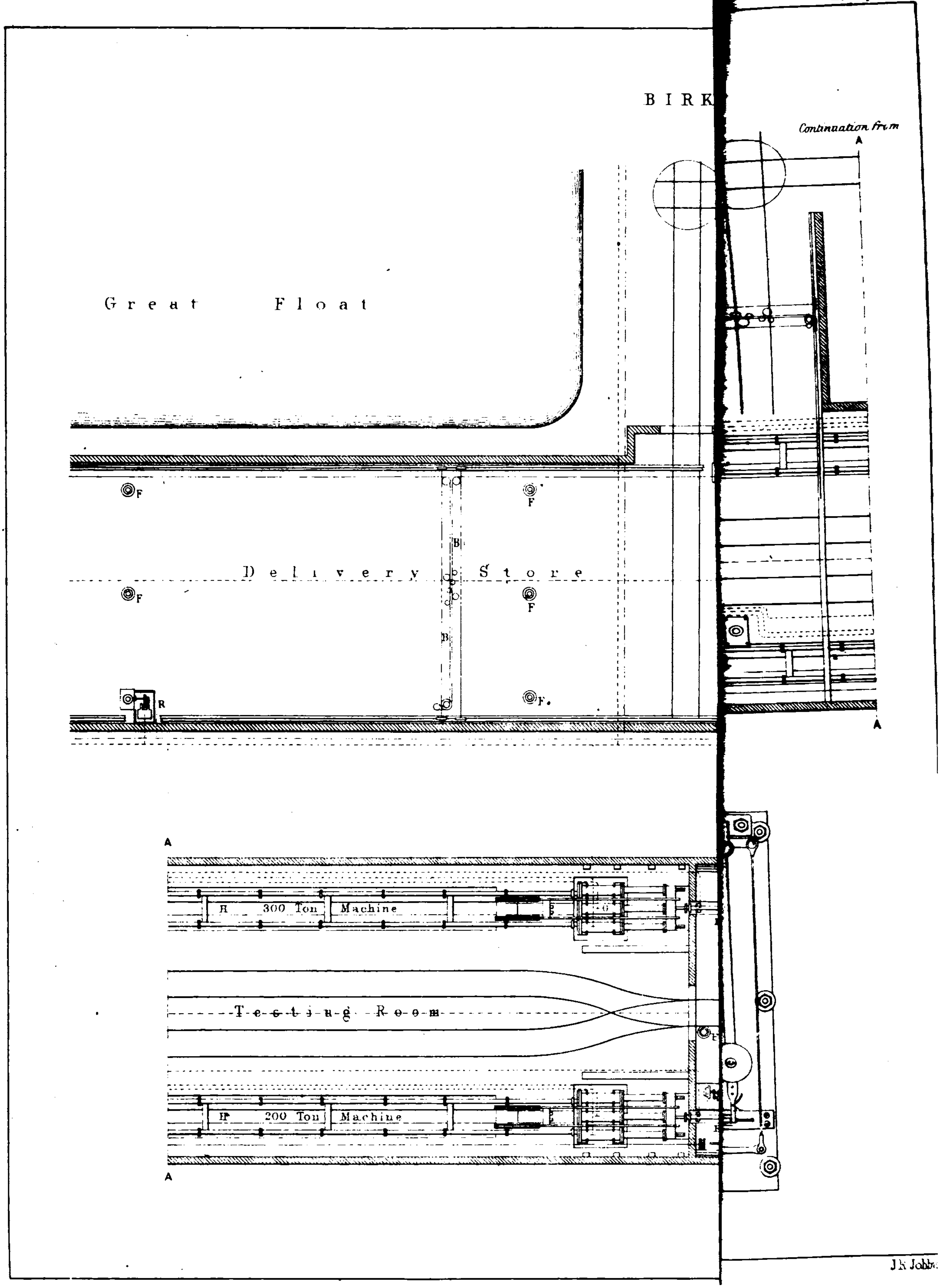
The following is an abstract of the discussion on Mr. John Fernie's paper, on the above subject, which appeared in this Journal for October, page 295.

Mr. James Yates said, the course adopted by the International Decimal Association, in order to obtain a solution of this question as to the best unit of length, had been to send a series of eleven questions to all the persons who were supposed to be best qualified to judge upon the subject; and the answers having been received, four meetings were held in London, to which all such persons were invited; and on that occasion Mr. Whitworth's system of accurate measurement was exhibited and explained. The result of the discussion of the question at the meetings was that a report was drawn up and circulated, in which it was, recommended as eminently desirable that the unit of measurement should be of such a length as might be adapted to measure the greatest variety of objects, and in the most numerous cases likely to occur in daily life; and that it should be visible at a glance of the eye, and easily carried about and manipulated: and it appeared that for these purposes the inch or the foot would be too short, and the fathom too long; and that a measure of about the same length as the ell, the yard, the metre, or the second's pendulum, was to be preferred, of which there were important reasons for selecting the metre as the universal unit. The inch indeed seemed at the outset very unsuitable to become the basis of a universal system; and although for English mechanical engineers it might be a very convenient measure, yet even for their purposes he was not satisfied that it would be better than the metre, by the use of which he thought all measurements in mechanical work might be made with equal nicety and accuracy. In the ordinary transactions of daily life the commonest and most universal measurements might be taken as those associated with textile manufactures; and the metre being a measure suitable for cases of this kind would be the most convenient for common use and eligible as the standard unit of lineal measurement. For example, an order for 13 metres of silk or 64 square metres of carpet was simple in expression, and would convey a clear conception of the quantity, if the metre system were adopted, and the unit would be very near the yard now used for the purpose; whereas with the inch as the unit, the equivalent expressions of 510 inches length or 99,000 square inches respectively, were very inconvenient and not very easily conceived. Such illustrations showed clearly the inconvenience of using a small unit; and led to the conclusion that, in fixing a standard unit of measurement, it was necessary not to have regard to any special purpose exclusively. In aiming solely at the small measurements that predominated in mechanical engineering work, the inch might be the best; but when a standard was required for all sorts of measurement, the inch was in his own opinion unsuitable for general use. For the purpose of minute subdivision every advantage was presented by the metre which was attainable by the inch; since the accuracy of minute measurements depended not on the scale, but on the instrument, which of course could be made equally applicable to any scale. The most recent instrument for minute measurements in connection with the metre system was that of M. Perraux of Paris, which was shown in the Great Exhibition of 1862, and afforded the means of measuring to 1-3000th of a millimetre (about 13 millionths of an inch); and for all practical purposes that was probably as minute and exact a measurement as was required. It should be remarked that Mr. Whitworth himself, who had recommended the inch to be adhered to for mechanical engineering work, objected to the prototype yard from which the inch was supposed to be taken, because it could not be seen or used; and had shown that it was hardly to be called a measure at all, and was inapplicable and of no value whatever in mechanical operations. The Astronomer Royal too had admitted that the chief value of this standard yard was its convenience for geodetic operations. For these purposes, however, the metre was at least equally eligible; and the difficulty that was anticipated from converting the present measures of this country to the metre system, on account of the number of decimal places required, would be met by the use of ready reckoners, specially adapted to all the purposes of commerce; these would be requisite until the metre was fully established in general use, after which the need of any such aids would cease. With regard to the relative population in favour of the inch and the metre respectively, he believed the numbers given in the 'Almanach de Gotha,' as the population at the present time of all the countries in the world, were generally accepted as the best authority on the subject; and from these data he had come to the conclusion that the population in favour of the metre should be taken as about three times that using the inch, instead of the majority being in favour of the inch as argued in the paper. Russia with a population of 74 millions appeared to have been put down as favourable to the inch, because it used the "sagene" of 7 feet English, or 84 inches. This measure, which was the Russian fathom, had been fixed, at a time when the length of that fathom was very uncertain, by Peter the Great, who decided that it should be exactly equal to 7 feet English. It has been stated however by Mr. Kupffer, the imperial superintendent of weights and measures in Russia, that although the inch was known in Russia as the 1-84th part of their standard unit, it was not used by any means in the same manner or to the same extent as the inch was used in England: on the other hand he instanced many points in which the present weights and measures in Russia approached very nearly to the metric system; and he expressed his opinion that it would be easier for Russia to adopt the metre system than for England to do so; and he decidedly considered the metre system was preferable for Russia to the inch system. A report has also been presented to the Minister of Finance, by the Imperial Academy of Sciences in St. Petersburg, in which the adoption of the metre was recommended for Russia; and there was therefore some ground for saying that Russia was decidedly tending to the adoption of the metre. The different states forming the Germanic Confederation had formerly been exceeding confused in their weights and measures, and had recently appointed commissioners to devise a uniform system, who recommended the adoption of the metre system throughout all Germany. A meeting of the several representatives was then held at Frankfort-on-the-Maine, when all the states except Prussia agreed to adopt the recommendation of the commissioners; and at length, in 1863, when the statistical congress was held in Berlin, Prussia also gave in its adherence to the metre system: thus all Germany might now be fairly reckoned on the side of the metre. Moreover Germany had for a long time past made a partial use of the metre system, the half kilogramme having been employed as the standard unit of weight in the custom house, the post office, the railways, and other public departments. In India also there was a movement going on which was favourable to the metre system, and recent extracts from the 'Madras Times' showed that that district of India was considering the subject and inclining to the metre. On the whole therefore he thought that Germany and Russia should be added on the side of the countries favourable to the metre, and India should at least be omitted from the number for the inch; and the population favourable to the metre would then be more than 200 millions, in comparison with about 70 millions actually using the inch at the present time.

Mr. F. P. Fellows observed that, in connection with the question of population, as bearing upon the adoption of the metre as the unit of decimal measure, was the amount of the home produce exports from this country to the countries favouring the metre system and to those using the present English weights and measures. It appeared that in 1861 the value of the home produce exports to countries using the metre system amounted to as much as 55 million pounds, while the exports to countries using the English system came to only 24 million pounds; further, that in the eight years from 1853 to 1861 the exports to the former countries had increased in value from 32 to 55 million pounds, while those to the latter countries had actually decreased in the same time from 43 to 24 million pounds.

Mr. C. W. Siemen's said, there was one misconception frequently entertained in this country with regard to the metre, namely, that as the metre was the basis of the system it must necessarily be taken as the unit of measure in all instances. This was not at all the case in France however, where, although the metre was the basis of the system, the millimetre was really the unit in mechanical engineering, and mechanical drawings were figured not in metres, but in millimetres. He found the millimetre was a very convenient unit for setting out small mechanical work; for being equal to about 1-25th inch it was smaller than 1-16th inch and larger than 1-32nd inch, and was therefore just such a dimension as a workman could still readily appreciate in following a drawing. Of course the millimetre without further subdivision would not suffice to measure with such wonderful precision as was attained by Mr. Whitworth's system of contact measurement, which had been carried out in connection with the inch divided decimally. But for such accurate measurements the unit of measure employed was of little consequence, since any unit could be decimally subdivided to such an extent as to give the required degree of accuracy; and under the metre system the millimetre was subdivided for the very minutest descriptions of work into 100 parts, called centièmes, each of which was equal to about 1-2500th inch, and was therefore as suitable for very small measurements as the thousandth of an inch. Moreover, independent of the metre being so convenient a measure for ordinary commercial purposes, and already so extensively adopted, he thought it deserved serious consideration whether it would be wise altogether to abandon a measure of some such length as the yard or the metre, as would be the case if the inch were taken as the unit of measure. He agreed that in respect to its verification the metre was not an absolute length; but that was really not a matter of consequence, since, if the quadrant of the earth's circumference were measured a hundred times, each measure would be likely to differ from all the rest; and if the measurement were taken several hundred years hence, perhaps the earth itself would have slightly altered in size during that period. The verification of the metre was therefore dependent upon the accuracy of copying an original standard, just the same as in the case of verifying the inch; and this original standard would always be referred to, instead of measuring the quadrant of the earth over again. It was nevertheless of some importance that the unit of length should be a measure referable to the size of the earth, because it was then easily applied to geographical and even astronomical purposes; and in this respect the metre had an advantage as the unit of length, in being approximately an even decimal subdivision of the quadrant of the earth's circumference. He concurred entirely in the desirability of having a system of measure in which there should be a direct decimal relation between lineal, square, and cubic measure, and between these and weight, as had been explained to be the case under the metre system. It had been correctly explained that the metre afforded a very great facility for ascertaining the weight of any bulk of material, its linear dimensions and specific gravity being known. There was then the least demand made upon the memory, since the specific gravity of different substances was all that had to be borne in mind, instead of a number of practical rules having to be recollected, which were applicable to one material only. The product of the cubic dimensions of any substance in metres multiplied by its specific gravity gave the weight of the substance in tonnes, being almost identical with English tons, or in kilogrammes when the decimal point had been shifted three places to the right. Upon the whole he considered it would be far better to adopt the metre system in this country, in accordance with the other nations who were already using it, than to decimalise a separate unit, which would never work afterwards in harmony with the rest of the world.

Mr. J. Scott Russell remarked, that the metre system possessed unquestionably the great advantage which had been pointed out, of a direct decimal relation between the measurement of any bulk and the weight of that bulk, without requiring anything to be remembered beyond the specific gravity of the substance under consideration. In his own work of shipbuilding he had found that it would be a great help to all calculations connected with ships, if there were a habit of thinking in some unit which bore an exact integral proportion to a ton of water: and it was the fault of the present inch and foot that neither of them gave any convenient factor in relation to a ton of water. For a ton of water consisted of 35·955 cubic feet, and the long decimal fraction was so inconvenient that he had been led to get rid of it in his experiments with models by adding so much salt to the water as should make it weigh exactly 35 cubic feet to the ton. It so happened that the water containing that amount of salt was a tolerably fair average of sea water; and he had made all his calculations in shipbuilding upon water of that description, on account of the convenience of the simple factor connecting cubic measure with tons. The metre had in this respect an advantage over the inch or foot, and he thought it was so great an advantage in practice for engineering and shipbuilding purposes, that although he agreed in the advantage of decimalising


BIRK
Continuation from
A
Great Float
Delivery Store
F
B
R
A
300 Ton Machine
Testing Room
200 Ton Machine
A

J. R. Jobb.

the inch for mechanical engineering work, he was opposed to adopting any system which would require all measures first to be reduced to inches, and then to be transformed to the metre scale for comparison with the rest of Europe. The advantages of decimalising the inch, however, were limited to the class of work in which the inch was most involved as the unit; and he did not think it desirable to go further and extend the inch system so as to include the measurement of long distances, such as miles, since it was evidently impracticable to think of miles or similar long measurements in inches.

THE CHAIN-TESTING ESTABLISHMENT AT BIRKENHEAD.

(With an Engraving.)

In the last number of this Journal a paper, by Sir William Armstrong, on "Chain-Testing Machines," appeared, in which the author gave a description of the apparatus for testing chain cables and anchors recently established at Birkenhead, and which was designed by and carried out under the superintendence of the engineering firm of which Sir W. Armstrong is a member.

Through the kindness of Sir W. Armstrong we are now enabled to give a plate showing the machinery used for the purpose at Birkenhead, and the arrangement of the respective parts of the building. The paper before alluded to contains a description of the establishment; and the following references will render the plate now given readily understood. The letters of reference refer to similar parts throughout the whole details of the machinery:—

Receiving Store.
A. Weighing Table.
BBB. Overhead travelling cranes worked by ropes.
CCC. Driving gear for rope cranes.
DDD. Capstans driven from shafts.
EE. Returning rams.
FFF. Snatch heads.

Testing Room.
GG. Hydraulic Presses.
HH. Testing floors.

Proof Indicating Room.
II. Lever indicators.
JJ. Pendulum indicators.
KK. Loaded and Ram indicators.

Examining Room.
LL. Examining benches.
MMM. Hearths.
NN. Cranes.

Heating Room.
OOO. Ovens for heating chains.
PPP. Stoke holes.

Blacking Room.
QQ. Blacking trough.

Delivery Store.
R. Capstan and Hydraulic engine.
Fig. 1, Pendulum indicator J.
Fig. 2, Section of cylinder and piston of pendulum indicator to enlarged scale.

Reviews.

Report of the Commissioner of Patents for the year 1862. Washington: 1864.

The annual Report of the Commissioner of Patents of the United States for 1862 has been received within the last month. It consists of two thick octavo volumes, one of which contains a copious index of the patents granted within the year, with an alphabetical list of the names of the patentees, and abstracts of all the specifications; the other volume is filled with illustrations. The number of patents granted and designs registered to citizens of the United States amounted to 3,438; to subjects of Great Britain 39; to subjects of the French empire 33; and to the subjects of other foreign governments 11, making a total of 3,521. The number of patents the terms of which had been extended was 22; and the patents expired in the year amounted to 648. The money received for the grant of patents, for copies, and for recording assignments, amounted to 164,899 dollars, and the expenditure to 182,240, thus showing a deficiency of 17,341 dollars. The preliminary examination which each claim for a patent undergoes in the United States is the principal cause of the large expenditure, of which 121,870 dollars were paid in salaries and to temporary clerks. In England, as is well known, every application for a patent is granted unless it be opposed by some competing inventor, but in the United States 1,517 applications were refused by the examiners within the year, and had they exercised their powers with strictness not half of the 3,521 patents that were added to the list in 1862 would have been granted. The small sum of money for which a citizen of the United States can secure a manufacturing and trading monopoly induces those who fancy they have made an improvement in any manufacturing process to rush to the patent office, to claim protection for the imagined invention; and amidst the crowds of applications it is impossible to give that careful examination to the specifications which is necessary to ascertain whether the alleged improvements are new. We may venture to say that even in this country, where the fees for obtaining a patent are five times greater than in America, not one-fourth of the patents granted have any validity; and the vast number of obstructive and valueless monopolies thus created affords the strongest argument to those who object to give any inventor the right of property in the works of his own creation. The following enumeration of some of the patents granted in the United States in 1862 with the same titles, is sufficient to show that of those inventions patented even in the same year there must be many that have no distinctive differences, and when there is added the vast numbers of patents in former years granted for similar objects, we may be assured that, notwithstanding the vigilance of the examiners, they must have passed very many similar claims for patent rights. There were granted 13 patents for beehives, 20 for steam-boilers, 29 for boots and shoes, 11 for lamp burners, 30 for churns, 11 for corn shellers, 13 for car couplings, 40 for cultivators, 22 for water elevators, 16 for steam-engines, 32 for breech-loading firearms, 20 for revolving firearms, 16 for grain separators, 45 for harvesters, 30 for lamps, 18 for locks, 12 for breech-loading ordnance, 10 for tobacco-pipes, 12 for ploughs, 29 for pumps, 21 for sewing machines, 13 for skates, 17 for stoves, 42 for washing machines, and no less than 40 for machines for wringing clothes. It appears from a tabular account of the business of the Patent Office for 26 years ending the 31st December, 1862, that a great increase in the number of patents took place in 1854, and that they continued progressively to increase until 1861. In 1837 the number issued was 435, in 1853 it had increased to 958, in the following year the patents issued were more than doubled, and in 1860 they had increased to 4,819. The next year there was a fall to 3,340, and in 1862 the number amounted to 3,521.

The descriptions of the inventions are necessarily very brief to be all included in one octavo volume. As an example of the manner in which the patents are described and illustrated, we extract from the report the two following abstracts of specifications for inventions of different kinds of

Bridges.

A. McGuffie, of Rochester N.Y.—*Improvement in Truss Bridges.*—Patent dated March 25, 1862.—A number of hollow sections of cast or wrought iron are constructed with their ends bevelled so, that by abutting against each other, or against interposed angular blocks, as to form the arch. Iron posts intersect the arch between the sections, and serve to sustain the roadway, the lower parts being connected by wrought-iron links. Top chords and braces are also used, as shown in the engraving, the object being to prevent buckling, and obviate lateral vibration.

Claim.—The combination of the arch sections AA, Fig. 6, Plate 36, (either with or without the interposed heads or blocks BB,) the posts CC, the joint blocks E, the links DD, diagonal tension rods *aa*, top chords FF, and lateral braces *cc*, the whole arranged substantially as specified.

George Heath, of Little Falls, N.Y.—*Improvement in Wrought-iron Bridges.*—Patent dated May 27, 1862.—The straining beams of the bridge are composed of wrought-iron plates, having vertical plates or webs secured centrally to their under sides by angle-irons. The braces are of V-shaped form, and are constructed similarly to the straining beams with which they are connected by rivets. The lower parts of each brace are connected by a horizontal plate, each of said parts terminating in a thimble, through which, and the horizontal plates, the chords of the bridge pass. Extending from and below the straining beams are rods, the lower ends of which terminate in eyes through which the chords also pass. The flooring timbers are supported upon needle beams, which consist of vertical metal plates having an angle-iron at their upper and lower edges, which form recesses or chambers at each side to receive the flooring timbers.

Claim.—First, the combination of the diagonal double or forked braces B (Figs. 7 and 8, Plate 36), straining beams A, vertical rods E, and chords C, substantially as and for the purpose set forth.

Second, constructing the straining beams A and braces B of wrought metal plates and angle-irons, connected together by rivets, substantially as and for the purpose specified.

Third, securing the lower ends of the braces B and vertical rods E to the chords C by means of the thimbles *j* and lock-nuts D; but this is only claimed when used with the peculiar arrangement of the rods E, braces B, and straining beams A, as described.

Fourth, the needle beams F, constructed as shown, when used in combination with the chords C and applied thereto, as set forth.

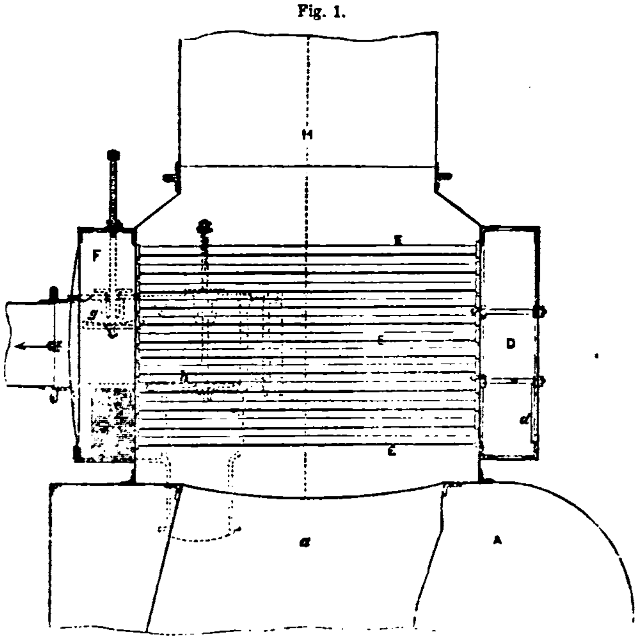
Recent Improvements in the Steam-engine: being an Introduction to the Catechism of Steam-engines. By JOHN BOURNE, C.E. London: Longman and Co.

A Catechism of the Steam-engine: new edition. By JOHN BOURNE, C.E. London; Longman and Co.

Mr. Bourne's popular book 'A Catechism of the Steam-engine," has reached the eleventh edition, but the work itself has undergone little change, for the author has judiciously adopted the plan of noticing the requisite additions—" the last touches of improvement and the most accredited maxims of present practice"—in a separate discourse, instead of incorporating such new information in the body of the work itself. By this means the possessors of the former editions may obtain the additional matter without being compelled to repurchase the whole work. This smaller volume is entitled "Recent Improvements in the Steam-engine," and it is profusely illustrated with drawings and diagrams of the most recently invented applications of steam-power. The author, in his somewhat stilted phraseology, says he trusts "that it will be found to answer its intended purpose of giving an accurate and vigorous outline of contemporaneous engineering knowledge in its most select manifestations, and that it will set the reader face to face with the works and opinions of those who are justly accounted leaders of the art, so that he will be able to feel that he has been brought up to the highest point of information yet reached by the most eminent practitioners." We extract from this recent addition to the work the following account, with illustrations of the modern practice of superheating steam:—

"The practice of superheating the steam before permitting it to enter the engine is now very generally pursued, especially in steam vessels; and the innovation has been productive of a material saving of fuel in many cases. It is found in practice that if the steam is superheated to a temperature exceeding 315 degrees, the hemp packings of the stuffing boxes will be burned, the oil or tallow used in the engine will be carbonised, and the cylinders and valves will be liable to be grooved

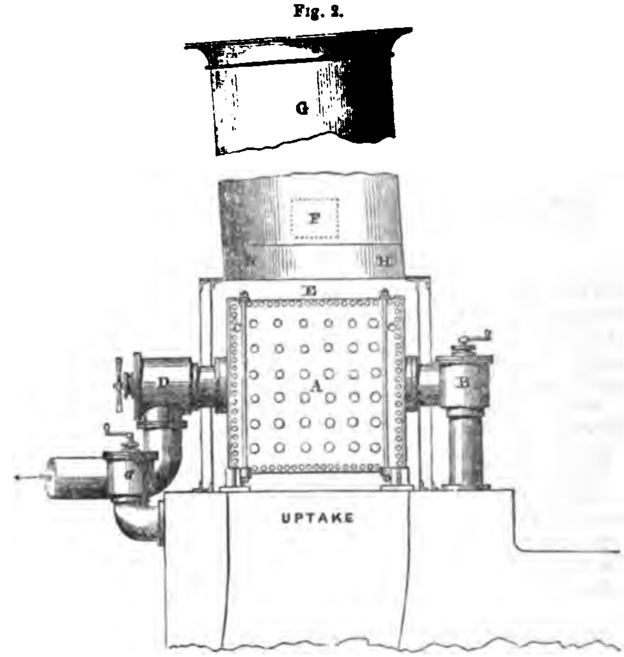
Fig. 1.



Superheating apparatus of S. S. Oleg, by R. Napier and Sons. 1860. Longitudinal Section.

and injured by the heat and friction of the rubbing parts. In boilers already producing dry steam, and possessing an adequate amount of heating surface, the saving in coal accomplished by superheating common low-pressure steam to this extent may be set down as about 10 per cent.; and although a larger economy than this has been obtained in some cases, the increased advantage is to be imputed to the acquisition of an increased heating surface, whereby the heat has been utilised in drying the steam that previously ascended the chimney—rather than to the superior efficacy of a given quantity of heat when distributed in the assigned proportion between the water and the steam. Upon the whole, superheating is now rather on the decline; at all events, it is not now carried much beyond that point which suffices to dry the steam, and to prevent the steam within the cylinder from suffering partial condensation, either by external radiation or by the generation of power. But condensation is equally hindered by the application of a steam jacket; and high-pressure steam worked expansively in jacketed cylinders, combined with surface condensers in the case of steam vessels using salt water, is now regarded as the most promising expedient of economy.

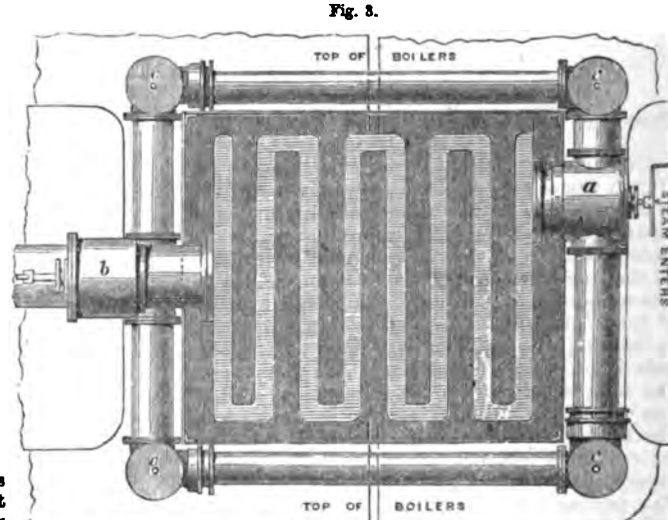
Fig. 2.



Lamb and Summers' Superheating apparatus, 1860. Vertical section.

The construction of superheaters is very various. But in most cases the steam is sent through a faggot of small tubes set in the smoke at the root of the chimney. An example of this arrangement is given in Fig. 1, which is a representation of the superheater introduced by Messrs. R. Napier and Sons into the steamer Oleg, belonging to the Russian Steam Navigation Company. A is the boiler, and *a* the uptake of the boiler; *d* position of inlet valve connecting boiler with superheater; D and F inlet and outlet chambers of superheater; E tubes through which the steam passes; *g* double outlet stop-valve chest, in which *g* connects superheater to steam pipe, and *h* connects boiler to steam pipe direct. H is the chimney. The smoke in ascending the chimney impinges on

Fig. 3.



Lamb and Summers' Superheating apparatus, 1865. Ground plan.

the tubes transmitting the steam, whereby the steam is heated to the required extent.

In Lamb and Summers' superheating arrangement, a narrow rectangular pipe or chamber—which winds in a zigzag manner like the flue of a flue boiler—conducts the steam backwards and forwards amongst the smoke at the root of the chimney, until finally the steam debouches in the steam pipe. This superheater is shown in Fig. 2, where A is the winding rectangular chamber; B the stop valve for admitting steam into the superheater; C stop valve for letting steam pass from the boiler to the engines without passing through superheater; D stop valve for

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P. W. BARLOW'S CAST IRON TUNNEL & EXCAVATOR

Fig. 3.

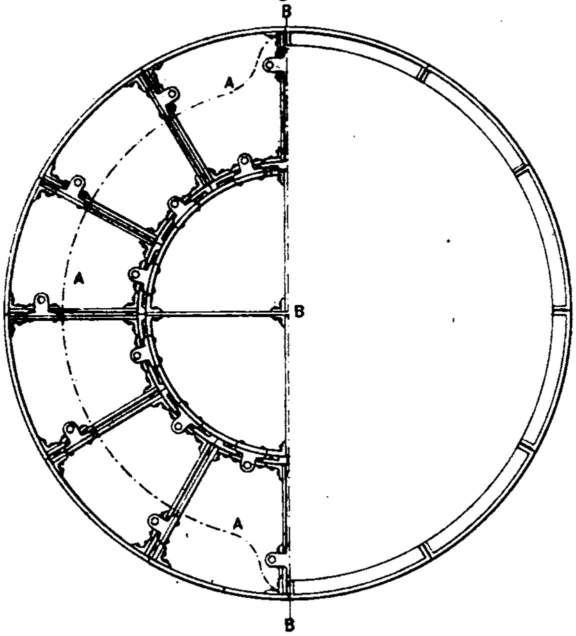


Fig. 4.

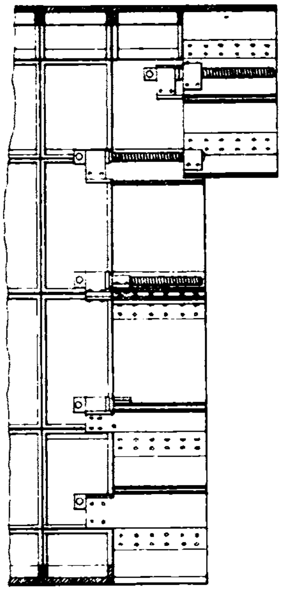


Fig. 5.

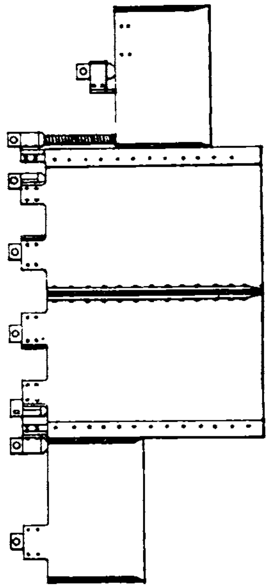


Fig. 1.

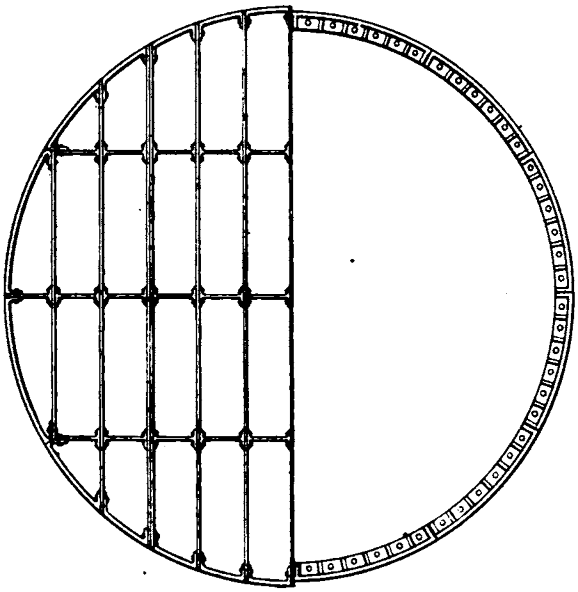


Fig. 2.

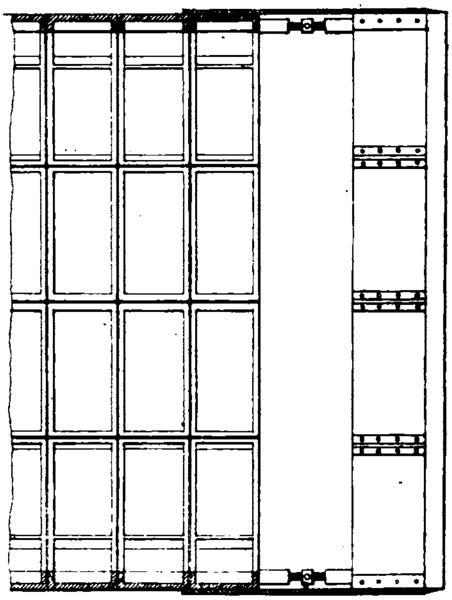


Fig. 7.

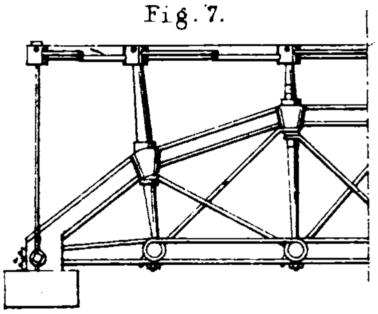


Fig. 8.

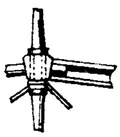
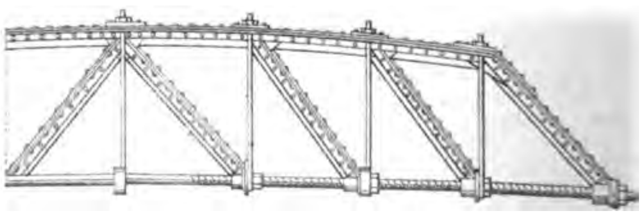


Fig. 6.



IRON GIRDERS.

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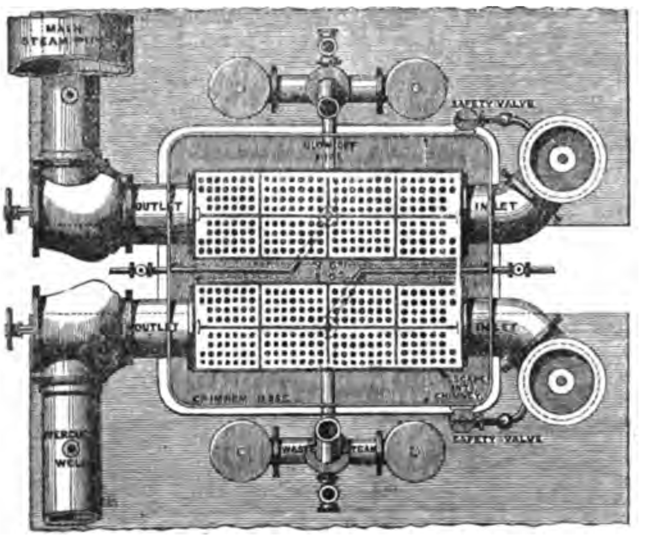
shutting off superheater; G is the chimney; F is the door for getting into it, and HH is a ring or cooming, over which the chimney passes, and the space between which and the chimney is filled with fire-clay to keep it tight.

Another example of Lamb and Summers' superheater is given in Fig. 3, which is a ground plan of the superheater as applied to four boilers, collectively of 400 horsepower. The steam space is 4 inches wide, and the smoke spaces are each 6½ inches wide. The winding length through which the steam is conducted is 51 ft. 9 in., and the

Fig. 4.



Superheating apparatus of Great Eastern, by Boulton, Watt, and Co. Ground plan.

height of the winding chamber is 5 ft. 7 in. The total area of heating surface in the superheater is 600 square feet, which is just 1½ square feet per nominal horse power. The steam issues from the boiler through the stop valves *c c c c*, enters the superheater through the stop valve *a*, and escapes through the stop valve *b*.

Another form of superheater is shown in Fig. 4, which is the superheater constructed by Messrs. Boulton and Watt for the steamer Great Eastern. This superheater consists of a square chest placed over the uptake at the foot of the chimney, and filled with vertical pipes through which the smoke passes. In this case the steam passes on the outside of the tubes, whereas in most cases it passes through the tubes as shown in Fig. 1.

A common proportion of surface given to superheaters is 4 square feet per nominal horsepower. But this is quite too much, and 1½ square feet per nominal horsepower is sufficient. As however, the nominal horsepower is so indefinite a quantity as regards the boiler, it will be preferable to fix the surface of the superheater at ·3 square feet per cubic foot of water evaporated. It is of course necessary to be careful in introducing superheaters not to contract the area for the ascent of the smoke up the chimney, which should be left quite as large as before.

Practical Specifications of Works executed in Architecture, Civil and Mechanical Engineering, &c. By JOHN BLENKARN, C.E. London: E. and F. N. Spon. 1865.

This book consists chiefly of specifications for works of various kinds that are likely to occur in the practice of the engineer and the architect. They are arranged under the heads of: 1. Road-making, drainage, and fencing; 2. Architecture; 3. Engineering. There are also examples of agreements for building and for leases, and reports upon works proposed to be executed. The remarks made by the author in his preface upon the generally low estimation in which the literary, as compared with the artistic, portion of professional duties is held by students, may easily be verified by observation; but this difference is probably greater than would exist if the facilities for acquiring proficiency in the two arts were more nearly upon a par.

The sources to which the student can refer for models of specifications are few; while the nature of the work renders it peculiarly desirable that the mind should be refreshed and the information enlarged by the study of numerous examples. There is in our exhibitions and illustrated architectural works that which tempts some minds to acquire a power of making showy sketches, to the neglect of the proper study of construction and detail, without which their designs are either vague or impracticable. Yet, to be able to comprehend the details of a work and to write a specification that shall be clear while it is concise, setting forth in an orderly arrangement things intended to be done, so as to convey a clear idea of them to the reader, is to possess an accomplishment which is at once a pleasure and a power. Of the method of acquiring and practising this art the author does not treat, but in publishing this selection from documents that have been used in his own practice, and in that of one or two other gentlemen, he has made a useful addition to the works available for reference on this important subject. Several of the specifications are illustrated with plans and sections, and there are some bills of quantities and schedules of prices, forming, in the whole, a considerable body of information upon works of engineering and architecture.

ON THE BEST MEANS OF RELIEVING THE STREET TRAFFIC OF THE METROPOLIS.

By JOHN IMRAY, C.E.

(*With an Engraving.*)

PLANS for relieving our streets of a portion of the enormous traffic with which they are now over-loaded have been from time to time suggested. The subject has received the attention of several parliamentary committees, and has occupied the minds of many eminent engineers. Its importance, so far from being lessened by the completion and projection of metropolitan railway lines, appears to be augmented; for the streets, instead of being relieved by these new arteries of circulation, suffer more than ever from that plethora of traffic which threatens at times to render them totally impassable. The principal effect of the greater convenience and economy of railway transit is to create a new set of passengers: to induce those to travel who did not travel before; and those who travelled rarely, to make their journeys frequent. The experience of all main and country lines shows this result; nor can it be doubted that a still more marked effect will attend the adoption of metropolitan lines. Neither must it be forgotten that, as metropolitan lines have been opened, new country lines, or additions to former lines, have been made; that a greater number of travellers are thus brought to the Metropolis; and that a large increase has been effected in the traffic of goods to it, through it, and from it. But, however the facts may be accounted for, the streets of London were certainly never more crowded than they now are. The Omnibus Company pays now a better dividend than it did before, and it requires greater vigilance and more careful supervision on the part of the police to prevent the great thoroughfares from being constantly blocked.

It is estimated that not less than 700,000 persons enter and leave the City proper daily; at least half as many enter and leave the other portions of the Metropolis; and there is thus a total daily influx and efflux of more than a million of persons. The number of vehicles daily circulating in the four great thoroughfares which radiate from the Bank, viz., Poultry, Moorgate-street, Cornhill, and London-bridge, amounted in 1862 to the enormous aggregate of 40,000, as against 33,000 in 1850; and this number is considered to be steadily on the increase.

In the presence of such facts as these, it may not be considered inopportune that the attention of the public should be called to the consideration of some practical measures for dealing with this question. My own thoughts have been more particularly directed to it lately, in the course of consultation with Mr. P. W. Barlow, C.E., as to the best mode of applying stationary power for working railways with frequent stations, and as to the construction of iron tunnels for underground railways. I have read attentively the evidence laid before the parliamentary committees, and I cannot concur with many of the views expressed in that evidence, for they appear to me to be founded upon erroneous mechanical bases. I therefore think it most desirable that, before further capital is expended, and before the inhabitants of London are committed to a system which may not be the best, the whole question should have that full consideration which is due to the magnitude of the interests involved in it. Throughout the evidence given before the parliamentary committees, except that of Mr. Hemans—to which I will presently refer—there appear to me to run two assumptions, erroneous in themselves, and leading to erroneous conclusions. They are—1. That in order to relieve street traffic, metropolitan lines must be in connection with and form part of existing railway systems. 2. That subterranean lines must be excavated from the surface.

1. With regard to the first of these assumptions, I must contend that railways intended to relieve the street traffic must, as nearly as possible, take the place of the conveyances now employed for that traffic. Their trains—or rather successive single carriages—must be extremely frequent, their stations very close to each other, and therefore their stoppages frequent; and their lines must be parallel or coincident with those of the thoroughfares which require relief. Even if all the principal railways were connected with each other, and with the great centres of business, those connections would be fully occupied by the through traffic. For the internal circulation, properly so called, a system totally distinct and independent is needed, a system which is incapable of subserving the purpose of railway connection without great inconvenience to the short-stage passengers on the one hand, and to the long-stage travellers on the other. The very circumstances which have made many lines avoid points of importance—that is to say, the value of the property and the crowded condition of the thoroughfares—are those that demand special railway accommodation; and the points that are now avoided are those which most require the application of some better system. Again, the conditions of great lines extending from the Metropolis far into the country are very different from those of lines devoted to internal circulation. In the one case it would be expensive, dangerous, and in every way inexpedient, to reduce too much the magnitude of the trains, and proportionally increase their frequency; and travellers starting on a long journey make their arrangements to suit the hours of the trains. But, for internal traffic, the frequency of trains cannot be too great; for persons desiring to pass from one part of the City to another do not and cannot lay their plans so as to suit particular hours of departure, but must find a conveyance ready at every moment. Again, unless a railway could take up and put down passengers within a few hundred yards of their points of departure or arrival, it would be comparatively useless for the relief of internal traffic. A passenger who has to take a cab or an omnibus for half a mile will as readily take the same conveyance for a mile or two miles, because the loss of time and inconvenience of changing and waiting at stations more than compensate for the superior speed over part of the ground.

To fulfil all the exigencies therefore of internal traffic in such a city as London, it is not, I believe, too much to say that there must be, coincident with the great thoroughfares, a system of railway accommodation in which the trains shall start every two or three minutes, the stations recurring every 300 or 400 yards. The evidence of Mr. Hemans, C.E., on this point is as follows:—"I have an impression very strongly that there must be two, if not three, systems of railways in London to do any good. For instance, my impression is, that railways will be needed, and will probably be made, in London for local traffic, such as omnibus traffic, that need not necessarily have any connection with the general system of railways. They may begin at one point and terminate at another, without having either level or rails in connection with the through system. In fact, I believe it may be found more convenient to have such railways as that for many purposes; and next, I think that to make goods trains traverse across the Metropolis, will require separation from the passenger trains eventually."—*Metropolitan Railway Commission, 24th* July, 1863, p. 143.

2. The second assumption which appears to me to vitiate much of the parliamentary evidence is, that subterranean lines must be excavated from the surface. Granting this to be true, the cost of purchasing the houses and land, the danger to the adjoining property, the inconvenience during the excavation of the works, and the great annoyance resulting from the working of the lines, are sufficient reasons for avoiding the great centres of industry and traffic, and for selecting lines which are too far removed from those centres to be of any value in relieving them of their overgorged circulation. Indeed, if this assumption be assented to, there is almost an end to the whole question with which we have to deal. It may therefore be worth our while to inquire whether there are not means of constructing railway lines underground through the most crowded parts of the Metropolis, without opening a single yard of the surface except at stations, and without disturbing, in the slightest degree, the levels of the ground, or interfering with the stability of adjacent buildings.

It has been said, with justice, that whenever a mechanical want is really felt, mechanical means of supplying it are sure to be forthcoming. Ingenuity appears to follow the ordinary laws of demand and supply, and in almost all the great inventions of our time we have examples of the truth of this observation. Nor, generally, when the demand occurs is the supply of a niggard character; for England, fertile in many products, is in none more so than in those of mechanical invention. I am, therefore, prepared to see, before the lapse of many months, numerous plans for constructing subterranean lines without opening the surface or disturbing foundations; because that, I am convinced, is a desideratum, and when it is acknowledged to be so, many active brains will be at work on the solution of the problem. It is sufficient for my present purpose to indicate one plan, proposed by Mr. Barlow, which, whatever other merits it may possess, has at least that of priority. It is a plan which appears to me thoroughly practicable, easy of application, and economical; and, as I believe it has not yet been made public, I will endeavour to explain it briefly.

Mr. Barlow proposes for railways, where they are to pass beneath a town or under a river, to construct underground a tunnel or tube of iron, made in short lengths, bolted together by internal flanges, each length being formed of segments, also bolted together. The pieces are thus comparatively small, light, easily transported and handled, and they can all be fitted together before they are buried. In front of so much of the tube as has been placed *in situ*, there is a circular shield with sharp steel front edges, and a cylindrical ring behind capable of sliding telescopically over the front end of the tube. The mode of carrying the invention into effect will be better understood by reference to our plate, where Fig. 1 shows half elevations of tunnel and excavator; Fig, 2, a longitudinal section of same. Figs. 3, 4 and 5 are similar views of another modification of a somewhat differently arranged tunnel and excavator; Figs. 4 and 5 being sections at AA and BB. The front, or face, of the shield is divided into compartments by ribs, also having sharp steeled edges, and each of these compartments can, if necessary, be covered in tightly in case the excavators should meet with water or quicksand, which might deluge the works if the whole or a large portion of the front were open. A portion of the tube having been placed *in situ*, the shield being in front, with its ring covering the last length, precisely like the lid of a tin can, the excavators inside the tube dig out the earth from the various compartments in their front. The whole shield is then pressed forwards by screw-jacks, hydraulic, or other convenient pressure, until there is room to fill in a new length of tube between the shield and the front flange of the tube already laid. The cylindrical back of the shield being necessarily larger, by its own thickness, than the exterior of the finished tube, on being advanced, leaves a narrow annular space around the tube. This space may be filled by injecting, through holes in the tube, cement in a liquid state, which, on setting, will not only fill the vacuity, but also make the jointings of the flanges tight, and form an efficient and durable coating for the metal of the tunnel. As each length of tube would be not more than 2 feet, each successive advance of the shield would not exceed 2 feet, and thus there would never be more than 2 feet of unsupported ground. There need not, indeed, be so much, for in case of a very loose or free soil the process of injecting the cement might go on during the advance of the shield, so that not an inch of length would be left unsupported. Mr. Barlow does not confine himself to this particular mode of constructing or operating with the shield; but, as these are questions of technical detail, I abstain from entering on them, considering it sufficient for my present purpose to show that there are possible methods of effecting the object in view.

The sinking of iron cylinders to considerable depths in the London clay is an operation now perfectly well understood, and one of no practical difficulty. Mr. Barlow proposes to perform the same operation horizontally instead of vertically. He does not propose to advance the whole tube, but merely the shield, filling in the tube in short lengths as he proceeds, and using the fixed portion as an abutment for pressing the shield still farther in advance. It would thus be practicable to construct a tunnel, of a cheap, strong, and substantial character, without either opening the surface, or interfering in the slightest degree with the stability of adjacent or superincumbent structures.

There is still one other part of the subject which is deserving of the most careful consideration. I allude to the power employed, or mode of traction adopted in such lines. I believe I correctly represent the public feeling when I say that locomotives are quite out of the question. Giving those engineers who have made the locomotive what it is, every credit for their efforts and success, and admiring as, I do, the locomotive as one of the greatest triumphs of human ingenuity, I must yet affirm that, for such a purpose as this, it is utterly inapplicable. And this for many reasons, among which I may particularly note its size and weight, its loss of useful effect in moving its own mass, its loss of time in starting and hindrance in stopping, and, above all, the annoyance of its smoke, steam, and noise, which render underground lines almost intolerable. The very measures that have been adopted in order to diminish the unwholesome and disagreeable effects of a locomotive in a tunnel tell against it in useful effect, for they add to the mass that has to be moved, and involve complexity in the details of the machinery, and, consequently, greater risk of accident. Besides, if it be granted that stations must occur every 300 or 400 yards, there would be no time for a locomotive either to start or to stop a train in that short space; and the trains being very numerous —one every two or three minutes—the number of locomotives required would be so great, and the risk of accident so magnified, that this scheme of traction could not for a moment be entertained.

If, then, the principle of locomotive traction must be abandoned, we must enquire into the best substitute for it. And here we are limited to two systems of propulsion. One is that of a traction, or impulse sustained throughout the whole or greater part of the trip, whether by a rope or by atmospheric pressure, or by other means that have been or may be devised. The other system is that of a greater impulse given during a small portion of the trip, leaving the momentum of the train to carry it over the rest of its journey. Some of the advantages attending the system of partial or initial propulsion having been already clearly pointed out by Mr. Barlow, I will explain the views which I have been led to form, without contrasting in some points the two systems to which I have adverted. I do not now propose to contrast Mr. Barlow's system with that of locomotive propulsion, for I have assumed that locomotives are inapplicable to the object we have in view. I have to contrast it only with systems of continuous propulsion effected by stationary power; and I believe I shall be able to show that Mr. Barlow's system presents many advantages in all cases where stationary propulsive power is adopted. In this particular case the conditions of the problem are—1. Very short stages of 200, 300, or, at most, 400 yards. 2. Very frequent trains—one every two or, at most, three minutes. 3. Very small trains, consisting of one or at most two carriages. And for the solution of this problem it may be assumed that the system of propulsion is not to be applied to lines existing, but that the lines themselves can be devised so as to suit the most approved system of propulsion.

The principle of continuous propulsion may be likened to a gradient of moderate inclination extending the whole distance over which the train has to move. The principle of initial propulsion resembles, on the other hand, a gradient of much steeper inclination extending over only a small part of the distance. The problem thus theoretically reduces itself to the question as to which is the line of quickest descent from one given starting-point to another terminal point situated at a lower level, and at a distance of several hundred yards from the starting-point. This line, as we know, is not the inclined straight line joining the two points, but is a cycloidal curve, having rapid descent at first, and approaching more and more nearly to the level of the terminal point as it proceeds. A body descending through a given height in this curve reaches the terminal point much sooner than it would attain if it moved in the straight line, or in any other curve. And, conversely, if the transit must be effected in a given time, the difference of level may be less when the curve of descent is cycloidal than when it is of any other character. So far therefore the principle of initial propulsion excels that of continuous propulsion in economy of time with a given power, or of power with a given time.

But there are other conditions which have to be taken into account. The train has not only to be started and propelled along its course, but has to be stopped on attaining the terminus. The force necessary to retard, and finally to arrest its movement, corresponds with an adverse gradient, and this, so far as time is concerned, must partake of the same character as the gradient for starting. The question, therefore, resolves itself into this:—Given two points, distant from each other, say 300 yards, and situated at different levels, what is the nature of the curve joining them, so that a body, starting from a state of rest, shall run down the slope from the one point and up the slope to the other, attaining rest on arriving there, or retaining a small residual velocity, in the least possible time with a given difference of level, or in a given time with the least difference of level? That curve, it is needless to show here, is of a cycloidal character, having its most rapid descent at first, gradually approaching the level, and again rising towards the terminus.

In making these observations, I am aware that railways cannot generally be made in cycloidal curves; but for subterranean lines, with frequent stations, I see no reason why this principle should not be adopted; and for this view I might quote the authority of a great intellect, that of Dalton, who suggested such a plan many years ago. I mean simply that, whatever be the nature of the propelling power selected, it should be graduated according to the law with which gravity acts in the cycloidal descent; and, so far, I am bound to express my accord with the views which Mr. Barlow has laid before you, for those views are founded upon the correct principle, which I have endeavoured roughly to illustrate.

Even in existing cases, where stationary power is applied to propulsion, I am bound to conclude that modifications made in the direction proposed by Mr. Barlow would be of advantage in economising power with a given time, or economising time with a given power. And this economy becomes more marked, the more frequent the stoppages and the more numerous the trains. In prospective cases, where the arrangements have to be devised, it is therefore most important that this principle should be kept in view. Nor do I think that it would be difficult to devise those arrangements in such a manner that the power, instead of being subdivided, with a portion planted at each station, might be concentrated at one convenient point, and communicated by fluid pressure, or other means, to the different subdivisions of the system.

Florence.—Dante's house.—The present capital of Italy promises to become not only one of the finest but even one of the largest cities on the Continent. Preparations are made to purchase the house in the Via St. Martini, supposed to have been the birthplace of Dante; but the owner makes difficulties in the price demanded. An appeal has been made to the poet Alessandro Manzoni, to petition the senate for an order of expropriation.—The municipality of Turin has named a commission to choose a site for a new burial place. The secretary of state has given leave to expropriate the houses of Camaldali di St. Lorenzo for the establishment of a central market in the limits of Via dell' Amiento, Via Romita &c., which is one of the great projects in contemplation. In some of the newly built districts, the option has been left with the proprietors, to execute the plans at their own expense on their own lands.

Oleaginous Mineral.—The discovery in New South Wales of mineral shale producing kerosene oil is likely to prove of importance. If the colony have not oil springs, and may even never be able to find them, it possesses in abundance the material out of which oil can be manufactured. The oil can be extracted cheaply, and the process at the present price leaves a good profit. The consumption of kerosene oil in these colonies is large and is increasing, and, even when local demands are supplied, there is a foreign market in the East easily accessible. In addition to the oil, there is a demand for the mineral itself. It is found to be valuable for the production of gas. Some of it has been experimented on at the Sydney gas works, and some at Melbourne. Some has been sent for trial to the gasworks at Singapore. All that has been done at present has been experimental; but these experiments are so conclusive that capital is being freely adventured in the enterprise. Machinery is being set up for distilling the oil, and before long the first supplies may be expected in the market. The principal deposit at present discovered is near Hartley, in the valley of the Lett, and within a few miles of the line traced for the Great Western Railway. It is very similar in character to the Boghead mineral of Scotland, but of a superior quality, and the seam is a very fine one. It has yet to be ascertained how far it extends, and at what points it may be conveniently accessible, but several parties are examining the country, and its mineral resources will soon be better known. The existence of the petroleum mineral at Hartley has been known for years, fragments of it lying on the surface of the ground; but its identity with the Boghead coal has never been shown, and but for the great American discoveries it might possibly have remained long neglected.

NATIONAL PORTRAIT EXHIBITION IN 1866.

The Lords of the Committee of Council on Education have determined to hold a National Portrait Exhibition at South Kensington, in the Arcades overlooking the Royal Horticultural Society's Gardens, which will be opened in April, 1866.

This Exhibition is based upon the suggestions made by the Earl of Derby, in a letter dated 6th May, 1865.

Their Lordships have constituted a Committee of Advice, consisting of the Trustees of the National Portrait Gallery and other noblemen and gentlemen.

Mr. Samuel Redgrave, to whose valuable labours the successful formation of the collection of Portrait Miniatures is chiefly due, has undertaken the special charge of directing the Exhibition, and Mr. Sketchley will act as Secretary.

Arrangements approved for the Exhibition.

1. The Exhibition is specially designed to illustrate English history and the progress of Art in England. It may be divided into two or three sections, representing distinct historic periods, exhibited in successive years, depending upon the number of the portraits received, and the space available for their proper exhibition.

2. It will comprise the portraits of persons of every class who have in any way attained eminence or distinction in England, from the date of the earliest authentic portraits to the present time; but will not include the portraits of living persons, or portraits of a miniature character.

3. In regard to art, the works of inferior painters representing distinguished persons will be admitted; while the acknowledged works of eminent artists will be received, though the portrait is unknown or does not represent a distinguished person.

4. The portraits of foreigners who have attained eminence or distinction in England will also be included, with portraits by foreign artists which represent persons so distinguished.

5. The Exhibition will be held at South Kensington, in the spacious brick building used for the refreshment-rooms of the International Exhibition of 1862; and these galleries, which are perfectly dry, will be fitted up expressly for the Exhibition, and patrolled day and night by the police.

6. All charges for the conveyance of pictures accepted for exhibition by the Committee will be defrayed by the Department of Science and Art.

7. The Exhibition will be opened early in April, 1866. The portraits, for the purpose of proper arranging and cataloguing, will be received not later than the second week in February, and will be returned at the end of August.

8. The Science and Art Department, unless the owner objects, will take photographs of such portraits as may be useful for instruction in the schools of art, and allow them to be sold in the museum. Two copies of each photograph taken will be presented to the owner of the picture photographed.

9. The department cannot be responsible for loss or damage, but every possible care will be taken of works lent.

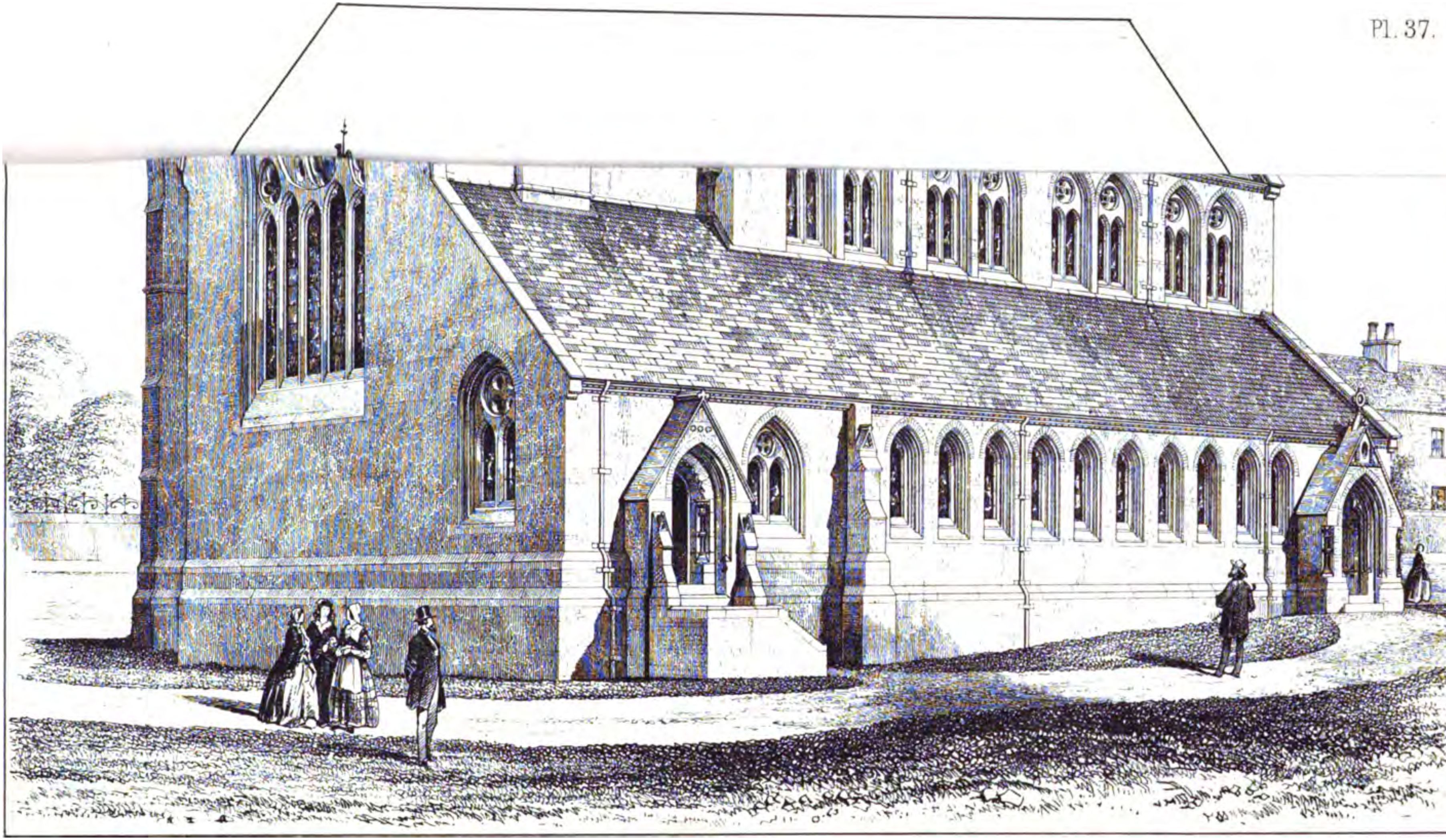
10. All correspondence, marked on the cover "National Portrait Exhibition," should be addressed to the Secretary of the Science and Art Department, South Kensington Museum, London, W.

Coloration of Glass.—M. Pelouze, having observed that the glasses of commerce were coloured yellow by carbon, sulphur, silicon, boron, phosphorus, aluminium, and even by hydrogen, was led to make a series of experiments for the purpose of ascertaining the cause of the identity of the results with such different reagents. The conclusions which he has reached, and which his experiments place beyond doubt, have a very considerable importance in reference to the possible perfection of our manufactures of glass. In fact, his first conclusion is that "all the glasses of commerce contain sulphates." These salts (sulphates of soda, potassa, or lime) render the glass more or less alterable by atmospheric agency, and come into the glass from two sources, either directly from the use of the sulphates as a flux, or from the presence of the sulphate of soda as an impurity in the commercial carbonate. The effect of their existence may be seen by examining many of the panes of glass in our windows which have been for some years exposed to the air, when the surface of the glass will be found to be corroded and partially opaque like ground-glass, and by examination under a magnifier will be found to be found to be covered with crystals. M. Pelouze found these sulphates present from 1 to 3 per cent. in all the commercial glasses window, plate, table, bottle and Bohemian glass: he also found 2 per cent. of sulphate of soda in a glass from Pompeii. The colouration is now easily explained, the reagents named above reduce the sulphates, and produce an alkaline sulphuret which has the property of giving the yellow colour. M. Pelouze proved his proposition by showing first, that when the glass materials were carefully purified from sulphates, no colour was produced by carbon, hydrogen, boron, silicon, phosphorus, or aluminium; and secondly, that an alkaline sulphuret added to the pure materials produced the colour.—*Acad. Sciences of Paris.*

New Town Hall, Hobart Town Tasmania.—The workmen are engaged in putting on the roof to the present portion of this handsome structure, and so far the work has done credit to Mr. Gowland, the contractor, and given general satisfaction. The necessary legislative enactment enabling the corporation to borrow £10,000 has passed the two houses of parliament, and is only awaiting the royal assent. According to present appearances, the town hall will be out of the contractor's hands about February or March next, that is, excepting the Elizabeth-street wing, about the erection of which at the present time the council have not yet given a decision. With the additional wing, however, this town hall will confessedly be the best building in the colony, and be alike an ornament to the city, and the establishing of the reputation of the architect, Mr. Hunter, and of the contractor.

The Ganges Canal.—There is a lesson to be learnt from the state papers on the Ganges canal, published in the supplement to the 'Gazette of India,' of the 26th ult. There has been a loss of thirty-five lakhs of rupees, as shown in the Secretary of State for India's despatch, No. 34, of 30th June, 1865, and the object of this article is to point out how these heavy losses may be avoided for the future, as well as to show the cause thereof. The Ganges canal was made by officers, who had a thorough theoretical knowledge of civil engineering, but who had no practical experience in canal works—hence they were obliged to learn as they proceeded. We know it was proposed seriously to construct railways in India on the same plan, and no doubt this would have been done had they been executed from imperial funds. We pointed out, in a former number, the heavy losses which had occurred from the appointment by Government of consulting engineers who had, some of them, never even seen a railway constructed in their lives—what would have been the result if the construction itself had been intrusted to officers of the like limited experience, instead of the fully qualified civil engineers who were sent out from England? Why, heavy loss, such as has occurred on the Ganges canal from a similar cause. Had one or more civil engineers of large experience in canal works been induced to come to India and act as consulting engineer to Government for the Ganges canal, and the local officers of great aptitude and real and local knowledge been employed for the execution, this large work, instead of having been a failure, would have been a success.—*The Calcutta Engineer's Journal*, Sept. 1865.

Ecclesiastial Buildings, Hobart Town, Tasmania.—Mr. Gowland's contract at £1000, for completing the present erected portion of the Roman Catholic cathedral in Harrington-street, is being carried out. The boundary walls are also to be built, and the cathedral grounds will be tastefully laid out. Mr. Hunter, architect, has the supervision of this work. Measures are being adopted for erecting a new place of worship at Clarence Plains, for the Colonial Missionary Society, on a site given by one of the residents of that locality. The chapel will be a plain, neat structure, at a cost within the means of the promoters, and adapted to the wants of the district. Ross church is to be taken down, and a new structure, after the design of the old one, to be erected for the Church of England in the township of Ross. At Fingal, the members of the Church of England have determined upon the erection of a new church, according to plans and specifications prepared by Mr. Hunter. The same architect has also furnished a design for a new Roman Catholic church at Longford, for which tenders are to be called without delay. The Congregational church meeting in Brisbane-street, Hobart Town, have resolved on the building of a new memorial church on or near the site of the present structure. A sum of £1000 was subscribed a few months ago, and invested in debentures, as the nucleus of the building fund, and collectors are actively engaged in getting additional subscriptions. The contemplated outlay will be from £4000 to £5000.



J.R.Jobbins.

CHURCH OF THE RESURRECTION (ANGLICAN)

RUE DES DRAPIERS-BOULEVARD DE WATERLOO,

BRUSSELS.

SOUTH EAST VIEW.

R. J. WITHERS, ARCHITECT, LONDON. 1864.

CHURCH OF THE RESURRECTION (ANGLICAN), BRUSSELS.

(*With an Engraving.*)

In continuation of the illustrations of this Church previously given in this *Journal*, for July last, we, this month, add thereto a further exterior view. The works are progressing but slowly: the primary cause being the difficulty in obtaining legislative consent to the completion of the conveyance of the site to English trustees. But this will, it is anticipated, be shortly overcome, when the work will be pushed on rapidly to completion. The reredos as shown in the interior view previously given, is to give place to a series of figures, &c. in mosaic, by Salviati.

A REVIEW OF THE POSITION OF ARCHITECTURE.*

By Robert W. Edis.

Of new buildings that have been completed in the past six months in London, none rank so high as, or are of more importance than, the giant hotels which have reared their lofty heads above the surrounding, comparatively speaking, pigmy houses; and the new hotels of Charing-cross and Langham-place, and the one now just completing in Holborn for the Inns of Court Company, are certainly great improvements upon the plaster palaces which have been before erected, and are more especially noticeable for the almost total avoidance of sham materials. Whether we like or dislike them in an art-point, is simply a question of individual taste; but they are certainly imposing, and free in a great measure from rococo ornament and plaster imitation; and anything in the way of example that may be set for the lessening of the evil of Portland cement, is certainly deserving of all praise, not only from an æsthetic point of view, but also because cement for external work in London seems to be of all material the worst, as can be exemplified by the smoky and abominably dirty appearance of most of the buildings in which it has been used; and it is only after successive and constant coatings of paint that he material in any way is made to look decent at all; and I should imagine that the triennial painting of these plaster palaces must be no small expense to their proprietors. The introduction of terra-cotta in the Charing-cross Hotel is especially worthy of our study and imitation.

Tastes differ as regards forms and styles, and examples to be imitated; and it is to be hoped that we may never entirely agree, for I cannot but believe that it is this difference of opinion that calls up the constant competition and aim to excel and improve. But the more we seek to insert in our designs, in place of the sham materials which even now hold so much sway, good and true materials, the higher will be the standard of our nineteenth-century architecture, and the more shall we call forth the thoughts and designs of the potter and other art-workmen, and open up and revive much that has been latent in materials and art-manufacture; and by endeavouring to design our buildings so that their decoration shall not only be constructional and real, but adapted for means that we may have at our disposal, instead of seeking for bad and unreal ornament, we may hope that we shall get manufacturers and others to compete in reviving the old, or in inventing new and better materials for our use; and so form a kind of fellowship with art-manufacturers which shall be of advantage to us as well as to themselves.

To combine with good, skilful, and artistic handicraftsmen must be our aim; and by so doing, I think we may yet hope to have the ancient decorations of the potter in all our buildings, and obtain, at the same time, something that shall not only give colour and effect, and by its plasticity be easily worked to our design, but also an inexpensive material, which in these days of cheapness and competition will be no small matter. Let us hope that the architects of our day may be different from those of the days of that great potter master, Josiah Wedgwood, and that instead of snubbing his suggestions for the use of terra-cotta ornaments and bas-reliefs in the façades and decorations of their buildings, we may take advantage of his suggestions, and not only seek to realise his day-dreams, but also take example by our Mediæval and Saxon forefathers, and make use of this and other materials, which their wonderful artistic and manipulative skill, as exemplified by hosts of examples still remaining to us, has converted into so much decorative and practical use.

Let us seek to do our *best* in all we do, and, to use the words of the able biographer of the life of Wedgwood, "Even as the men of science purify the atmosphere of our cities and towns, as assuredly they will, let our public buildings become, in the best sense of the word, palaces of art, and the interior of our houses shrines of simple taste in ornament and colour. Wall-linings of terra-cotta would do away with the barbarous taste of the paper-hanger and upholsterer, and floors of exquisite tilework would serve to border the warm embracing carpet. Here would be work enough for the potter and the artist; and in the chastity of colour and the purity of design we might rival antiquity, whilst true to the spirit of our generation.

I do not believe that this is any romantically conceived idea. Much lies before us, and if we will only earnestly strive to use all that God and nature have given us, and to work in fellowship and brotherhood with our fellow men, we may yet have in our day and generation some national—not, mind, a *new*—style of architecture, appropriate to modern requirements, which shall save us from the shame of being mere copyists of other men's work. Pray do not think that I ask you in any way to listen to any of the empty and idiotic talk about a *new* style, for, as has been writen by an eminent art-writer, "the essence of a style, properly so called, is that it should be practised for ages, and applied to all purposes;" but our aim should be, while studying the grand examples of ancient work that are left to us, to seek to design our work so that it may be not a mere pseudo imitation of Mediævalism, but in accordance with present requirements and modern inventions. I think we may, however, fairly congratulate ourselves upon having made some considerable progress in architectural design in the last few years, if in this great city we look at the buildings, both ecclesiastical and civil, that have recently been erected, and compare them with those of twenty years ago. Amongst churches lately built, there is one to which I would especially draw your attention, as being one of the best, if not the best, of them all, and one which exemplifies in an exceedingly good and beautiful manner how much can be done with plain honest brick,—I mean the church of St. Peter, at Vauxhall, by Mr. Pearson.

You will see in this church that everything that has been done, has been done thoroughly; there has been no scamping,—and, moreover, the architect has evidently in a way been bound down by the narrowness of wordly means, and has yet so designed his building, that hereafter, from time to time, may be added such decoration in the way of fresco painting, &c., as means may permit. There has been a careful avoidance of all attempt after "bizarre" ornament, and overflowing of paint and cement inlays Everything is simple and honest; no notchings, no chamfers, but all is substantial and good.

One great feature in this church, and one worthy of our study and imitation, is the brick-vaulted roof; and another, the large wall spaces or panels that are left to be filled up hereafter, when means permit, with that best of all art-decoration, figure subjects in fresco; and I cannot but think that we should be right in seeking to imitate this modern example set before us, and in saving the means at our disposal for figure subjects, as proposed here, rather than spending them in unmeaning conventional decoration, and lines, and zigzags, and dots, painted, or inlaid in cement, all over walls and roofs. Surely the purer and simpler the decoration is, the more it will be understood and appreciated.

There are many other notable churches lately erected in and around London, in all of which there is much to be studied and thought of, but amongst so many good ones it would be invidious to particularise.

Again, in the City, and in our streets, surely we must admit that great strides have been made towards improvement in the warehouses, public offices, and shops, that have lately been erected; I will not presume to individualise any one of these, but a walk through Lombard-street, Cornhill, Fleet-street, and others of the more crowded streets of London, will surely convince you that there has been "some shaking amongst the bones." Even our engineers are now calling in the aid of architects to design their stations, and in part their bridges; and I think that with the new stations at Charing-cross and Blackfriars, and those now building in Cannon-street and Broad-street-buildings, we shall have some reason to consider that our art is taking higher ground.

Even now, in this great day of capital and wealth, the great public companies, as well as private enterprise, are boring through, as it were, and destroying many of the slums of this

* From an address read at the Architectural Association.

great city, threading their way with quiet, progressive steps through old, narrow, and dirty byways, demolishing much that is ugly and inconvenient, and opening out new streets and new ways, which, so soon as time shall have enabled them to rebuild, will do something, I hope, to overthrow that criticism of our neighbours across the Channel, and convince them that we, in good old England, are not quite so destitute of taste as they would fondly imagine.

The new streets through Blackfriars to the Mansion House that the Metropolitan Board of Works are about making, and the improvements at Pimlico, on the Marquis of Westminster's estate, are all steps in the right direction; and some of us may yet live to see handsome streets of honest good buildings, and see them also free from the film of smoke and mist that at present are part and parcel of this great city; for I am sanguine enough to believe that improved skill and science will enable, not only public furnaces, but also private grates, to consume their own smoke, and thereby render us free from this curse and trouble, that makes our city show out so unfavourably compared with Paris and other modern continental towns.

Of course we may find fault with something, if so disposed; and it is not to be expected that, at once and entirely, we shall shake off the teaching of long years of bad taste; and in much of the new work it may be that there is too much striving after show and effect, rather than simplicity; too much copying of "bizarre" ornament and overlaying of decoration; but I cannot but think that, in due course, all this will rectify itself, and that, as our art-education increases, and our range of examples becomes wider—and, thanks to the iron way, which modern skill and modern science have interlaced half over the world, and are still interlacing, we are able each year, if we will, to increase our store of Mediæval study, and to see each year more of the art and art-work of our forefathers—so much the more will our ideas tone down and be simplified; and also, so much the more will the public, who by the same means can see all that we see, insist on a truer and better kind of art-work, and be satisfied with less ornament and more reality.

Not only in architecture proper, but in all its accessories, must we hope to see continual and increasing progress; and that, by diligently persuading our manufacturers and jewellers, upholsterers, and brass and iron workers, and all other trades which more or less have something to do with art-work—or, rather should have; for, at present we cannot say much for the art or the work that these gentlemen turn out—to either obtain the aid of artists to design for them, or, at all events, to employ a designer who shall have been more or less educated to his work, we may hope to get more taste and art design in everything around us.

Within the last few years the art of staining glass in England has been making rapid progress, and the works of many of the manufacturers of the present day may, I think, even bear comparison with some of the best old work. And why we should not be always able to do good glass now-a-days, after all the great improvements that have taken place, and the infinitely greater facility for obtaining materials of all kinds, is a thing much to be marvelled at; but until true artists—men who not only can draw the figure well and properly, but who also know how to colour—are employed to design and colour the cartoons, we can hardly expect much improvement in stained glass design. Some manufacturers have availed themselves of this aid, and in the cartoons of Mr. Holliday for the windows of Worcester College Chapel, at Oxford, which have been ably worked out by Messrs. Lavers and Barraud, we see the great desideratum of employing artists to design. But inasmuch as the artist soon rises above cartoon designing, and, as soon as he gets name and fame by some lucky Academy hit, no longer is willing to work at mere decorative work of this kind, so much the more does it become a necessity that our art designers should be educated in figure-drawing and colour to a much greater extent than at present; and by the aid of our Governmental schools (about the only good thing Government has done for art for a long time has been the establishing of these schools), let us hope that a better class of designers and art-workmen may be formed. So much for the design of the glass; and for the glass itself we must trust that manufacturers will eventually be able to give their glass somewhat more of the old texture and colour. Doubtless the glass of Chartres Cathedral windows, and all the other old stained glass, owes much to the hallowing and sobering influence of time, which has toned it down; but let us hope that, ere long, we shall get that exquisite jewel-like appearance and thoroughness, if I may use the word, of colour which the old glass has, instead of the vulgarity and gaudiness and crudeness of colour which pertain to so much of our modern stained glass; and from what has been done by several manufacturers, we may fairly hope that we are in the right way to have in our day stained glass equal to that of the thirteenth century; and yet see the churches of our time "blazoning with the radiance of jewelled and gem-like arabesques" and coloured crystal, instead of vulgar copies of bad foreign glass, and the still more vulgar commingling of crude and vulgar colours.

Again, with regard to metal-work, and the work of the silversmith and the goldsmith, how abominably bad most of it is. We either have heavy unmeaning masses of cast brass ornament, or else finnikin cut brass leafage and scroll-work, with just so much design as the ability of the manufacturer is able to insert. Why must everything we have around us be necessarily ugly? What can be more atrocious than the Brummagem cast bronze, or imitation bronze work, that hangs as gaseliers from our ceilings, or intrudes itself in endless form throughout our public and private buildings and our streets? Is it necessary that work with any design in it shall be dear? Or is our day and time a day of ugliness, that we cannot get design anywhere, and must put up with vulgarity?

In the times of the Greek and the Roman, and in the Mediæval days of Gothicism, cheap things were not ugly things. You may take up the commonest and most homely vessel, and you will find that its form is good. If you will look at the examples which have been preserved to us, and now find homes in our museums and private collections, you will find the commonest things were beautiful and in good taste. It is not that good art then was any cheaper than it might be now: it was because the appreciation of good detail and lovely form was innate with the people of those times: and they were so accustomed to see everything around them lovely and in good taste, that their art-education was self-taught; and thus each man became, as it were, an artist, and, as such, artistic workmen also.

I know that designed furniture costs no more than other work, when once you have taught your workmen how to make it; and the mould and making for a good design is no more expensive than that for a bad one. There is no necessity that cheap things should be ugly, or decoration vulgar: these things all become a question solely of design, which again in a great measure, turns upon art-education.

This brings me to speak of a matter that has been engaging the earnest attention of this Association for some time, and one which we shall have to consider and take action upon in some way, I hope, in the coming session. I mean that of "Architectural Examination."

It is now, I believe, some ten years back since this Association determined to take steps to establish a system of architectural examination, whereby a more definite professional status for architects might be obtained, so that, if possible, our profession should cease to be one in which any man, no matter how ignorant or how unqualified, could, if he so pleased, enter. Starting on the broad basis of endeavouring to work some general benefit for the profession at large—for such we must consider a recognised system of examination would of necessity be—we were desirous of obtaining for ourselves as architects a similar system of examination, and consequent professional recognition, as that which is necessary for all the other professions.

About a year after this, our Association, I believe, memorialised the higher powers above—the Institute, and, after much consideration and talking, the matter was taken up by them, and architectural examinations were inaugurated; but beyond the mere examinations we have at present got no further, and are practically in the same position as we were ten years back, except that those gentlemen who like to learn a certain number of lessons, and get the examiners of the Institute to hear them, and desire to pass an examination for their sole gratification and pleasure, can, if the numbers be sufficient, do so. Further than this they cannot go; at present the examination scheme, if I may be allowed to call it so, is a farce, always excepting that there is a certain amount of honour and credit due to the man who passes successfully the somewhat stiff examination; otherwise, there is no use in it—we still remain where we were. Any one may now have his name engraved on a plate, and set up as an architect; and the most ignorant and incompetent may still practise as such, and as such must of necessity militate to the detriment, not only of the cause of art and of educated architects themselves, but also to the imposition of the public, for they, the public, must of necessity judge of our art by the work itself; and when we see the result of some of the work of these gentlemen, who have thrown down the hod and taken up the pencil, we may well say that it is time that architectural examinations shall take place. I firmly believe that we shall have the good wishes and assistance of all well-wishers of architecture; but, on the other hand, it must not be expected that the young men of the present day—who, whether in practice for themselves, or working as clerks or pupils for others, have very often but little time to spare for any ephemeral undertakings—will devote long months of toil for reading and study to enable them to go up for the examination, simply, as I have said before, to pass it, or mayhap, as last year, to be rejected, not on their merits or demerits, but because the number arbitrarily fixed by the Institute as the smallest quantum to make an examination had not been made up. But let the Institute offer some tangible inducement, and there will not, I believe, be any lack of competitors.

That the Institute, as a body, will give this all-important matter their best and serious re-consideration, I cannot but believe; for those who have done so much for the cause of art in the last quarter of a century, and, of themselves, to raise the character of architects and architecture, will not, I am sure, be the ones to refuse to help their pupils and their sons in attempting to follow in their footsteps, and in their time from seeking still further to raise the standard of our rank. To them as our masters and teachers we owe much, and I hope we may, therefore, confidently look forward to having their advice and aid. But, on the other hand, let us not turn back: let us look forward, not backward, and not give up the good work which we have commenced: let us not undo what we have done by any short-sighted disgust or despair; but earnestly, manfully, and diligently strive for the object we have in view; still work and study amongst ourselves; and, I believe, in time our end will be obtained. In fact, we have ourselves, by the inauguration of our Life Class, at least shown our great anxiety to aid in carrying out the suggestions made to us by Mr. Scott and others, and I am glad to be able to say that in this we have been successful. Last year we had forty-seven members in the class, of whom more than two-thirds were members of the Association; and under the able superintendence and care of Mr. Poynter, the artist whose services we were fortunate enough to secure, considerable progress has been made, and to him and Mr. Tarver, the honorary secretary, I consider the Association much indebted. I trust that this year the numbers will be increased, and that members will show their appreciation of the scheme, and their desire also to carry it out, by joining this class forthwith. I feel quite certain that the drawing of the figure cannot be too strongly advocated, and that it is one of the most essential and necessary parts of an architect's education to do this well. If you do not learn now, you will never learn; and I cannot too strongly urge on the gentlemen of this Association the absolute necessity of doing what men a great deal better than I have been urging upon them for some time—viz., learning to be able to draw the figure with ease and facility.

Let us be able to design for the potter and for the decorator, and get them to mould the clay and paint the wall in fellowship with us; but before we ourselves can even hope to design well for them, it is necessary that we ourselves shall have diligently studied and gathered up the materials of our forefathers; shall have seen how their design and work were done, so as to be enabled to combine such experiences and such study with the necessities of modern requirements and the advantages which modern skill and modern invention have given to us. Do you think for one instant that, if our Mediæval forefathers had lived in our day and generation, that they would not have grasped at the many inventions and improvements of this nineteenth century? Do you think we should have small narrow windows, and coarse, bottle-ended knobs, settling like flies amongst them? No, I think not. I think that the men who could so beautifully design and work with the materials and the education they had before them, would have grasped at our modern inventions, and would have thrown some life even into cast-iron girders and plate-glass windows, and not have crossed our rivers and our streets with ugly straight lines of simply mechanical skill and human power. Into human power would have been thrown assuredly some art. They would, I believe, have done justice to the materials which, by the enlarged scope of invention and scientific skill, we nineteenth-century architects have to our hand; and surely there is no reason why we should not do likewise.

Of all things that tend most to harm the cause of art in this nineteenth century, I cannot but think that of narrow cliquism is perhaps the greatest; for surely cliquism is merely an extended form of egotism; and he who narrows the limits of his sympathy and help in art-life to the circumscribed circle of the few who think exactly with himself, surely is no well-wisher of art; for we must look on the world of our art from no narrow circle of our own, but from as wide a point of view as our education and minds will permit us; and the more we embrace within our gaze, the more likely are we to perfect the work that we love.

I am quite certain that the more young architects (I say young, because I am speaking to this Association) know of each other, and the more they meet together in good fellowship and friendship, the better it will be for them all. There is no need for all to agree on questions of art; we all probably differ in this matter, more or less, as we do in other things; but why should there be any necessity for constant fighting over the ashes of extinct mummies, and taking up the gauntlet for designs of centuries ago? Have we no design in us, no hope in us, no brain to work for ourselves, or must we divide into divers cliques, and swear and do battle for the leader of this and that clique, now rushing on to the bristling lances of the thirteenth-century French school, and now clashing swords with the champions of Early English; now up in arms for the true and original and national farmhouse and cottage architecture, and now swearing allegiance to the only and real style, the round-arched Gothic of France and Italy? We write and talk as if in this nineteenth century we were simply to form parties and opinions in defence of different schools, following out and swearing by different erections of the past; and the war wages bitterly on, and instead of the battle of the styles, we have the battle of the cliques, and when "clique meets clique," then comes the tug of war. Is there no general school? Must we, because we like this or that, say that all else is wrong? Surely not, and I trust this Association will look a little beyond the narrow arena of any so-called clique. There is no reason that our ideas and opinions should all be alike; but if we differ, let it be in a friendly manner, and rather than ignore those whose opinions are different, let us strive for interchange of thoughts and opinions, and to enlarge our own views. To compare thoughts and ideas will be, I am sure, to the advantage of us all. We are all students, earnest students, I hope; but the more we study together, and the greater interchange we have of honest opinions,—mind, not opinions taken from other men, but formed from our own honest convictions,—the more good shall we do to the cause we all have at heart.

HIGH-SPEED COMPRESSED-AIR HAMMER, FOR PLANISHING, STAMPING, FORGING, &c.*

By William D. Grimshaw.

(With an Engraving.)

The objects of this compressed-air hammer are to obtain a self-acting hammer with a great range in the force and rapidity of the blows, so as to be suitable for light forging, tilting, and planishing; or capable of being worked by hand with heavy blows for stamping when required; and also arranged to be driven by a belt from a shaft, in order to be applicable where direct steam power is not available. The machine consists of a force pump supplying compressed air to a reservoir, and a working cylinder and piston with hammer similar to those of a steam hammer, but worked with compressed air instead of steam, and having arrangements for varying the action of the hammer as required, and increasing the rapidity of the blows considerably beyond the speed of revolution of the driving pulley.

The hammer is shown in Plate 39; Fig. 1 is a sectional side elevation; Fig. 2 a front elevation; Fig. 3 a back elevation; Fig. 4 a plan partly in section; Fig. 5 a sectional plan through the hammer cylinder; and Fig. 6 a vertical section through air reservoir.

The double-acting air pump A, Fig. 1, is 8 inches diameter and 8 inches stroke, and is worked by a crank pin on the driving

* Read before the Institution of Mechanical Engineers.

pulley B; it has a solid piston fitted with cupped leathers, and cast-iron suction and delivery valves C, which are circular with flat faces, and each fitted with a light spring on the top to close the valve promptly. The interior of the hammer frame D forms the reservoir, into which the compressed air is delivered by the pump, and the pressure is regulated by the safety valve E, with a sliding weight or spring balance to alter the working pressure of the hammer. The piston F of the hammer cylinder is 4½ inches diameter, packed with cupped leathers, and has a full stroke of 10 inches. The compressed air is admitted below and above the piston alternately by the slide valve G at the top of the cylinder, and escapes by an exhaust port at the side of the cylinder H. The pressure of the air admitted to the cylinder from the reservoir D is regulated by the throttle valve I, worked by the foot treadle K; the throttle valve spindle is seen in Fig. 5, which is a horizontal section through the hammer cylinder.

The slide valve G is of cast-iron, and is shown separately to a larger scale, in different positions, in Figs. 7 to 11. It is faced both back and front, with the ports passing through to the back; and two adjustable cut-off slides J J, are placed on the backs for altering the points of cutting off the air. These are regulated separately by screws L L, which pass through the side of the valve-box, and serve to hold the cut-off slides stationary in any desired positions.

The side valve G is worked by a crank pin on the horizontal disc M, Figs. 1, 4, and 6, and this driven by contact with the vertical wheel N upon the shaft of the driving pulley B; the disc M is pressed down by a spiral ring O, upon the lower end of its spindle, as shown in the section Fig. 6, and the vertical wheel N is faced with leather on the edge, to give the required adhesion for driving it. This wheel N slides along the driving shaft upon a feather, and is shifted by the lever P, varying the speed of driving the disc M by acting upon it at different distances from its centre, and thereby giving a range of speed for driving the slide valve up to more than double the rate of revolution of the main driving pulley B. By means of the lever P, which is held in a series of notches, the number of blows of the hammer can thus be changed, without stopping it, from 150 up to 420 per minute, with the usual working speed of from 150 to 200 revolutions per minute of the driving pulley.

The valve spindle is connected with the crank pin on the driving disc M, by a connecting rod R, having a forked end, as shown in the plan, Fig. 4; and this can be at once disconnected by withdrawing the fork R, by means of the handle S. The slide valve is then worked by hand or foot by means of the lever T, when the hammer is required to be used for stamping; and the lever T is removed by drawing it out of its socket when the hammer is required to be worked self-acting.

An efficient hammer worked by compressed air is found very advantageous in many situations, such as where there would be material loss of power by condensation in bringing steam from a great distance, or where the damp from leakage of steam or the dropping of condensed water on the anvil would be objectionable, as in shops where bright steel is exposed, or where the planishing of bright work is carried on. The air hammer also meets the cases where horse-power or other power than steam is alone available; and it has an advantage in being always ready for work, not having any accumulation of condensed water in the cylinder and passages as in the steam hammer. There is also a saving in lubrication and in wear of the working parts, from their not being exposed to the heat of high-pressure steam.

In this air hammer the force, rapidity, and quality of the blow can be changed with great promptness and accuracy. The force of the blow is regulated by shifting the safety valve weight E, or by means of the throttle valve I, altering the pressure of air upon the top of the hammer piston; and the slide-valve motion admits of altering the rapidity of the blow instantaneously, giving also the means of obtaining a very high speed without involving any destructive tappet action, as the small slide valve G is alone required to be worked at the high speed. The arrangement of the cut-off slides J, gives the means of regulating the quality of the blow, from a full stamping blow, to a sharp pick-up blow, striking with any degree of lightness, and well suited for such work as planishing and shaping hollow ware; and by the use of the hand or foot lever T the hammer is readily and conveniently worked as a simple stamp.

Mr. Grimshaw stated, in reply to questions, that several of the hammers were now in use in Birmingham and the neighbourhood, employed for various stamping and forging purposes; also one at Glasgow for copper-smith's work, shaping and planishing vacuum pans for sugar refining, and one at Sheffield for steel tilting. The pressure of the air could be varied by altering the load on the safety valve, and the hammers had been worked at pressures of from 7 to 30 lb. per square inch; the ordinary pressure at which they were worked was about 20 lb. per square inch. One of the hammers had been at work for more than seven months in a smith's shop for ordinary work; and in that case it was employed also for blowing the fire in the intervals while the iron was being heated, by a connecting pipe being carried to the tuyere from the air reservoir. In stamping plate iron the hammer could be used for stamping the metal either hot or cold as might be desired. The greatest speed at which the hammer had been worked was 800 strokes per minute, and it could be driven at any number of blows below that amount. It was usually worked self-acting for any speed above 100 blows per minute, but below this it was generally preferred to throw the self-acting motion out of gear, and work it by hand; or in case the workman wanted both his hands free, the treadle gave the means of working the hammer by foot. The largest of the hammers yet put to work had a cylinder 8½ inches diameter, and a stroke of 28 inches; he did not know what pressure it was working at, but the pressure might be adjusted to any amount, from 5 lb. up to 40 lb. per square inch. The cost of such a hammer was about £180, and of a hammer of the size shown in the drawings about £50, the larger hammer requiring about 5-horse power to drive it, and the smaller about 1-horse power.

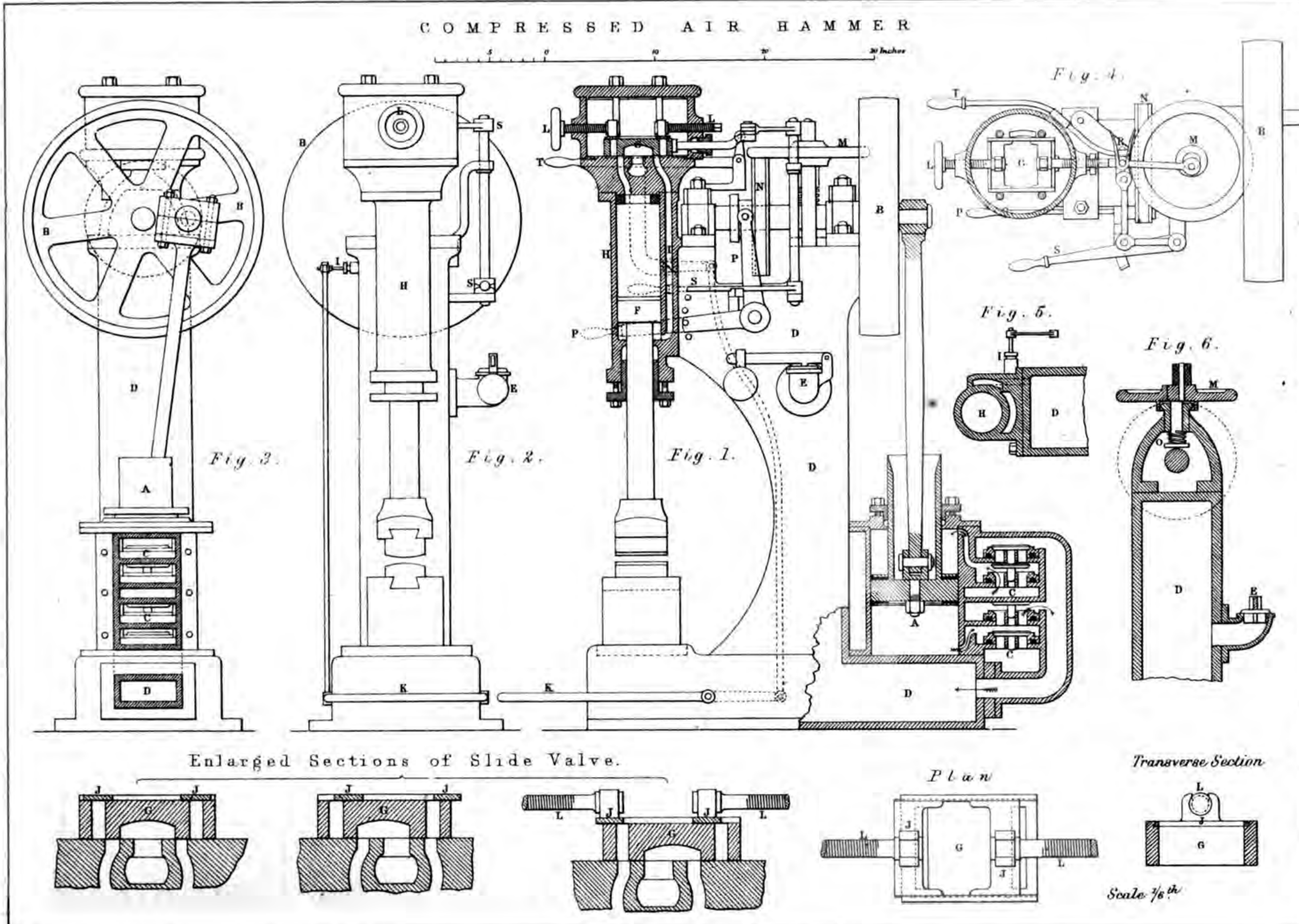
Mr. E. H. Carbutt thought the air hammer was not as suitable for steel tilting, and would not be able to compete with the steam hammer for that purpose, since its power was not to be compared with that of the steam hammer. The greatest advantage of the air hammer he considered would be for stamping small articles, in place of hand labour. Several steam hammers of from 4 cwt. to 10 cwt. were working in Sheffield, with which 500 to 600 blows per minute could be struck if required; and they were regularly working at 300 blows.

Mr. Grimshaw observed that in reference to tilting steel there was one of the air hammers now at work in Birmingham which was employed in drawing down steel; a bar of steel 4 inches long and ⅝-inch square was drawn down to a length of 14 or 15 inches with a regular taper, and 36 of these were produced by the hammer in 19 minutes in the ordinary work, which he believed it would be impossible to accomplish by any steam hammer at present employed. The average speed of the air hammer for that work was about 340 blows per minute in regular working, and that was as fast as the man could turn his hand for turning over the mould between each blow; the speed could however be increased whenever desired up to 600 or even 800 blows per minute. When the drawing of the steel was finished, the hammer could be stopped instantly, with a promptness which could not be attained with the steam hammer.

Mr. W. Richardson thought all that had been performed by the air hammer in steel drawing and other work could be accomplished well by ordinary steam hammers, as regarded both the rapidity and force of the blows. The main advantage he considered to be gained by the use of the air hammer would be preserving the die always dry and free from liability to droppings of condensed steam; there were many kinds of work in which a dry die was a matter of great importance, and for such cases the air hammer appeared admirably adapted; but for general work he did not think it could compete with the steam hammer.

Mr. Grimshaw mentioned that the steam hammer had been abandoned for steel tilting at some of the works in Sheffield, and the air hammer adopted instead, as it was found preferable for the purpose. At Messrs. Sanderson's works one of the air hammers had been at work for a considerable time for bolstering and forging knife blades, &c.; and at another steel works a shop was going to be built to contain six of the air hammers.

Mr. C. H. Adames said that he used to employ steam hammers for planishing hollow ware at his works in Birmingham, but had been obliged to abandon them for bright iron-work, on account of the droppings and moisture from the steam; and he had now put up for the purpose one of the air hammers described in the paper, which had been at work for ten months and had proved very successful, and had shown he considered a decided economy as compared with steam. He accordingly intended to remove two steam stamps of large size at present in use, and replace them by air hammers, which he was satisfied would answer well.


COMPRESSED AIR HAMMER
20 Inches
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Enlarged Sections of Slide Valve.
Plan
Transverse Section
Scale 1/8th
J.R.Jobbins

Mr. F. J. Bramwell remembered an air hammer being made by the late Mr. John Hague, about thirty-five years ago, which he believed was one of the earliest air hammers that had been made. It was worked as a vacuum hammer, by exhausting the air, instead of by compressed air, and was constructed for the purpose of planishing frying pans; and it worked with such an extraordinary rapidity that it was impossible to see where the hammer was in working, and the effect seemed more like giving one continuous pressure. That hammer was however wanting in the elegant contrivance for regulating the blows that was shown in the hammer now described; and he was particularly pleased with the mode of working the slide valve, by the neat arrangement of the friction wheel and disc running in contact with each other. He inquired how the surfaces of the wheel and disc had been found to stand in work, and whether there was much liability of their slipping; and what amount of repairs had been required to any of the hammers.

Mr. Grimshaw replied that in the first of these hammers that was put to work the surfaces of the friction wheel and disc for working the slide valve were merely iron against iron, and worked in that condition for seven months with only an occasional slipping when a little oil from the bearings happened to get upon the surface of the disc. Afterwards the bearing of the disc had been recessed, and formed into an inverted cup, to prevent any risk of oil getting upon the rolling surface; and the friction wheel had been faced with leather to increase its hold upon the disc and diminish the wear. No repairs had yet been required to any of the hammers at present in work, and the only accident that had occurred to any of them had been that the cylinder bottom got broken through an accident in the first hammer, which had been put up mainly with a view to testing the cost of working and the actual wear and tear of the several parts.

PARIS UNIVERSAL EXHIBITION OF 1867.

The Commissioners of the French Exhibition, to take place in Paris in 1867, have approved the following regulations, specially applicable to British and Colonial Exhibitors:—

Art. 1. The Universal Exhibition to be held at Paris in 1867 will be open for the reception of works of art, and of the products of agriculture and industry of all nations. It will be held in a temporary building on the Champ de Mars. Around the Exhibition building a Park will be formed for the reception of cattle and other live animals, and plants, as well as for those constructions and objects which cannot be exhibited in the main buildings. The Exhibition will open on the 1st of April, 1867, and will close on the 31st October following.

Art. 5. The Commissions appointed by the various foreign governments to direct the part which their respective countrymen will take in the Universal Exhibition are in direct communication with the Imperial Commission relative to the Exhibition of the works of art and other productions of their country. Consequently, the Imperial Commission will not correspond with foreign exhibitors. Products sent by a foreign exhibitor can only be admitted through the medium of the foreign Commission which represents him. The foreign Commissioners will also provide as they may see fit for the carriage, the reception, the arrangement, and the return of the productions of their countrymen. They must, however, conform to the regulations laid down by the Imperial Commission.

Art. 6.—Foreign Commissioners are requested to place themselves as soon as possible in relation with the Imperial Commission, and to depute some person to represent them. The duty of this representative will be to arrange the questions which refer to foreign exhibitors, and particularly those relative to the allotment of the whole space among the various countries, and to the manner in which each foreign section shall be arranged in the Exhibition building and in the Park.

Art. 7.—In order to facilitate the division of the space allotted to each country between the various classes of objects enumerated in Article 11, the Imperial Commission will place at the disposal of the representatives for their guidance, the plan of the arrangement of the French section of the Exhibition building, drawn on a scale of two millimètres to a mètre (1 inch to 41·6 feet or $\frac{1}{500}$). This plan shows the arrangement of the glass cases and counters suitable for each class of objects, as well as the shape, height, and other dimensions of the courts intended for each class. An analogous plan of arrangement showing the manner in which the portions of the Exhibition building allotted to each foreign country will be subdivided is to be transmitted to the Imperial Commission before the 31st October, 1865. Plans in detail, on a scale of two centimètres to the mètre, (1 inch to 4·16 feet, or $\frac{1}{50}$,) showing the place allotted to each exhibitor, and to each separate stall, are also to be forwarded with the list of exhibitors, by each Foreign Commission, before the 31st January, 1866, in order that in arranging the interior of the Exhibition building the Imperial Commission may be able to take into consideration the wants of each country.

Art. 8.—Each foreign country may claim, for the formation of a special park, the portion of the Champ de Mars adjoining the space allotted to it in the Exhibition building. The representative of each foreign Commission will settle with the General Commissioner the plan of the paths for the circulation of the public, and of the earthworks, which will be executed at the cost and under the direction of the Imperial Commission. Each representative will also arrange with the General Commissioner so as to leave at the disposal of the Imperial Commission the portions of the ground which may be in excess of the wants of his countrymen, or to obtain an additional piece of ground from the portions to which other representatives may have given up their claim. In order to facilitate as much as possible the arrangements of the foreign exhibitors in the portions of the Park allotted to them, the Imperial Commission will place at the disposal of the representatives for their guidance the plans adopted by the French exhibitors for arranging the animals, plants, model cottages, &c. (Appendix A.)

Art. 9.—An official catalogue of the products of all the foreign countries will be drawn up, showing the place which they occupy either in the Exhibition building or in the park. This catalogue will contain two alphabetical lists, one of the exhibitors, the other of the products exhibited. Foreign Commissioners are requested to send the information necessary for the preparation of the catalogue before the 31st January, 1866.

Art. 11.—In each section assigned to the exhibitors of the same country, the objects will be divided into 10 groups and 95 classes—viz.

1st Group.—Works of art (Classes 1 to 5).

2nd Group.—Apparatus and applications of the liberal arts (Classes 6 to 13).

3rd Group.—Furniture and other articles intended for dwelling houses (Classes 14 to 26).

4th Group.—Clothing (including fabrics), and other articles worn on the person (Classes 27 to 39).

5th Group.—Products (raw and manufactured) of mining (Classes 40 to 46).

6th Group.—Instruments, and processes of the common arts (Classes 47 to 66).

7th Group.—Food (fresh and preserved) in various states of preparation (Classes 67 to 73).

8th Group.—Live products and examples of agricultural establishments (Classes 74 to 82).

9th Group.—Live products and examples of horticultural establishments (Classes 83 to 88).

10th Group.—Objects exhibited with the special purpose of improving the physical and moral condition of the people (Classes 89 to 95).

The objects which are included in these groups are given in detail in the System of Classification (Appendix A) annexed to these Regulations. In order to avail itself of any suggestions that may be made by the French exhibitors and the Foreign Commissioners, the Imperial Commission reserves to itself the right to resolve, in the successive editions of this document, all doubtful questions to which this first publication may give rise.

Art. 12.—No work of art, or object exhibited in the Exhibition building or in the Park may be drawn, copied, or reproduced in any manner whatever, without the authority of the exhibitor who is the author of it. The Imperial Commission reserves to itself the right to authorise the taking of general views of the Exhibition.

Art. 13.—No work of art or object exhibited may be removed before the close of the Exhibition without the special authority of the Imperial Commission.

Art. 14.—Neither French nor foreign exhibitors will have to pay any rent for the space occupied by them in the Exhibition; but all costs incurred for fittings and decoration in the Exhibition building and in the Park must be borne by them.

Art. 15.—Frenchmen and foreigners, by the act of becoming exhibitors, thereby bind themselves to adhere to these regulations.

Art. 18.—Works by French and foreign artists, executed since the 1st January, 1855, will be received for exhibition.

Art. 19.—The following will not be received: 1. Copies, including those which reproduce a work in a manner different to that of the original; 2. Oil paintings, miniatures, water-colour paintings, pastels, designs and cartoons for stained glass and frescoes, without frames; 3 Sculpture in unbaked clay.

Art. 22.—The number and nature of the rewards that may be given in respect of works of art, as well as the constitution of the international jury who will be called upon to act as judges, will be decided hereafter.

Art. 23.—All the products of agriculture and industry will be admitted into the Exhibition with the exceptions and limitations mentioned in the following article.

Art. 24.—Detonating, explosive, and other substances of a dangerous nature will not be admitted. Spirits and alcohols, oils and essences, corrosive substances, and generally substances which may affect injuriously other products exhibited, or incommode the public, will only be received in strong vessels, specially adapted for the purpose, and of small dimensions. Percussion caps, fireworks, lucifer matches, and other similar articles can only be received when made in imitation and deprived of all inflammable ingredients.

Art. 25.—Exhibitors of products of an unwholesome and disagreeable nature will be bound to conform at all times to such measures of safety as may be prescribed to them. The Imperial Commission reserves to itself the right to cause the removal of any products, whether French or foreign, which by their nature or their bulk might appear injurious, unsuitable, or incompatible with the objects of the Exhibition.

Art. 36.—Exhibitors of apparatus requiring the use of water, gas, or steam are to state, when sending in their application for space, what amount of water, gas, or steam will be necessary. Those who wish to exhibit machines in motion are to state at what speed each of these machines is to be driven, and the motive power which it will require.

Art. 39.—The cost of packing and carriage of the goods sent to the Exhibition and of the goods which have been exhibited there, is to be borne by the exhibitors, both to and fro.

Art. 41.—The Imperial Commission will not interfere in any way between the contractors for the carriage of packages and the exhibitors in respect of the despatch and the reception of the goods. The exhibitors must therefore, either personally or by their agents, see to the transmission and reception of the packages, and verify their contents. If neither the exhibitor nor his agent be present to receive the packages on their arrival at the Exhibition, the carrier is bound to remove them immediately.

Art. 42.—Packages from foreign countries must be marked in such a way as to show distinctly from whence they come. The Imperial Commission will make arrangements with the Foreign Commissioners in order that these packages may be transmitted in accordance with the regulations specified in Article 40 for French packages; on this point, however, the Foreign Commissioners will adopt the course which they may consider most advisable.

Art. 43.—French and foreign goods will be received into the Exhibition from the 15th January, 1867, up to the 10th March following, inclusive.

Art. 44.—The Exhibition is constituted a bonded warehouse. Foreign goods intended for the Exhibition will be admitted into France, under bond, up to the 5th March, 1867, by the following ports and frontier towns: Dunkirk, — Lille, — Valenciennes, — Feignies, — Jenmont, — Vireux, — Givet, - Longwy, —Thionville, —Forbach, — Wissembourg, — Strasbourg, — Saint-Louis, — Pontarlier, — Bellegarde, — Saint-Michel. — Nice, —Marseilles, —Cette, —Le Perthus, —Hendaye, —Bayonne, —Bordeaux, — Nantes, — Saint Nazaire, — Granville, — Havre, — Dieppe, — Rouen, —Boulogne, —Calais.

Art. 45.—The Imperial Commission will issue special instructions relative to the period when the materials for the buildings, as objects for exhibition, the separate parts of machines and apparatus, heavy and cumbersome articles, and those which require masonry or special foundations, are to be brought into the precincts of the Exhibition. Such works are to be performed by the exhibitors and at their own cost, in accordance with the plans submitted by them for the approval of the Imperial Commission.

Art. 46.—The Imperial Commission will supply gratuitously the water, gas, steam, and motive power for the machines admitted under the regulation contained in Article 36. This motive power will, except in special cases, be transmitted by a horizontal main shaft, the diameter and the number of revolutions per minute of which will be made known by the Imperial Commission before the 31st December, 1865. The exhibitors will have to furnish driving pulleys on the main shaft, connecting pulleys, and intermediate shafting for the purpose of regulating the proper speed of the apparatus, as well as the belts necessary for each of these motions. Steam engines which require to be supplied with steam from their own boilers cannot be shown in the Exhibition building, and special directions will therefore be issued respecting them.

Art. 47.—All other expenses, such as the employment of workmen in the building, the reception and opening of packages, the removal and charge of packing cases, the construction of counters, stages, glass and other cases, &c., the placing of goods in the Exhibition building and in the Park, the decoration of the stalls, and the return of the goods, are to be borne by the exhibitors, French as well as foreign.

Art. 48.—The Imperial Commission will point out to exhibitors who may apply, contractors for the execution of their work and for the removal and custody of their cases; but they are at liberty to employ any contractors or workmen they may think fit.

Art. 49.—The various stalls and fittings may be erected in the Exhibition as fast as the buildings are completed; they must be commenced at latest on the 1st December, 1866, and must be ready for the reception of goods before the 15th January, 1867.

Art. 50.—The passages reserved outside the exhibiting space being strictly calculated for the purpose of circulation, packages and empty cases are not allowed to remain therein. Cases must, therefore, be unpacked as fast as they are received. The Imperial Commission will direct its own officers to unpack for the exhibitors, and at their risk and peril, the cases left in the passages intended for circulation. From the 11th to the 28th March, 1867, the goods already unpacked and placed in the stalls are to be arranged and displayed for exhibition. The 29th and 30th March are reserved for the purpose of a general cleaning. A review of the whole Exhibition will take place on the 31st March. The Imperial Commission will take all measures necessary to have the Exhibition complete in all its parts by the 28th March. It will, therefore, dispose of all those portions of space which, on the 14th January, 1867, are not occupied by stalls ready for the reception of goods, and of all those stalls which, on the 10th March, do not contain goods enough to fill them.

Art. 51.—Immediately after they have been unpacked, the cases that have been used for the carriage of the goods either in France or from abroad, are to be removed by the exhibitors or their agents. If they should fail to do this without delay, the Imperial Commission will remove the cases and packing, and will not be in any way responsible for their preservation.

Art. 52.—Special instructions will be published hereafter for the organization and arrangement of the products and objects for exhibition which are to be placed in the Park.

Art. 53.—The name of the producer will be affixed to the goods exhibited. The name of the retailer who usually acts as his agent may be added with the producer's consent. The Imperial Commission will, when required, make arrangements for the exhibition of goods under the name of the retailer, when they are not sent for exhibition by the producer.

Art. 54.—Exhibitors are requested to insert after their own names or the names of their firms, the names of those persons who have contributed in a special manner to the merit of the products exhibited, either as inventors or designers, or by some process of manufacture, or by some remarkable skill in the workmanship.

Art. 55.—The cash price of the objects exhibited and the place where they may be purchased may be stated. This information must be given upon all objects included in Class 91. In all the classes, the prices, if stated, must be adhered to by the exhibitor as respects the buyer, under penalty of exclusion from competition. Objects sold may not be removed before the close of the Exhibition without the special permission of the Imperial Commission.

Art. 56.—The Imperial Commission will take every means to preserve from damage the articles exhibited, but it will not hold itself in any way responsible for any loss by fire, or for any accident, damage, or injury, great or small, which may happen to them, from whatever cause it may arise. Exhibitors must take upon themselves the expense of insurance if they should see fit to avail themselves of that precaution. The goods exhibited will be watched by the necessary staff, but the Commission will not be responsible for any thefts or embezzlements which may be committed.

Art. 57.—A special notice posted in the Exhibition building and in the Park will make known the staff appointed to organize the interior of the building. It will also contain the names of the officers whose duty it will be to give assistance to the exhibitors, and to watch over the security of the Exhibition.

Art. 58.—A ticket will be delivered to each exhibitor, which will give him free admission to the Exhibition. This ticket will not be transferable. If it should be proved that the exhibitor has lent or given his ticket to some other person, it will be forfeited without prejudice to further proceedings at law. To secure the carrying out of this regulation, the ticket of admission must be signed by the holder, who will have to enter the Exhibition by certain prescribed doors only, and he may be required to establish his identity by signing his name in a book to be kept for that purpose.

Art. 59.—Exhibitors will be allowed to have their goods taken care of by the agents they may select, but they must be approved by the Imperial Commission. Personal tickets of free admission will be given to those agents under the conditions laid down in the foregoing Article. An exhibitor's agent can only receive one ticket of admission, whatever number of exhibitors he may represent.

Art. 60.—Exhibitors or their agents must not solicit visitors to make purchases; they will confine themselves to answering inquiries, to handing the address cards, prospectuses, and lists of prices which they may be asked for.

Art. 61.—The Imperial Commission will fix hereafter the prices of admission to be paid by visitors in order to be admitted into the Exhibition.

Art. 62.—An International Jury for making the awards will be formed, divided into nine groups, corresponding with the nine groups of the products of agriculture and industry enumerated in the system of classification. (Art. 11, and Appendix A.) The number, the nature, and the various grades of the awards, as well as the constitution and functions of the jury, whose duty it will be to apportion them, will be published hereafter.

Art. 65.—Immediately after the close of the Exhibition, the exhibitors must begin to pack and remove their goods and fittings. This operation must be completed before the 30th November 1867. After that date, the goods, cases, and fittings which may not have been taken away by the exhibitors or their agents, will be removed and deposited in a public warehouse at the cost and risk of the exhibitors. The objects which, by the 30th June, 1868, may not have been removed from that warehouse, will be publicly sold, and the net proceeds of the sale will be applied to some work of charity.

INDIA-RUBBER CONSIDERED IN REFERENCE TO ITS APPLICABILITY AS AN INSULATOR FOR TELEGRAPHIC CONDUCTORS.*

By William Hooper.

The difficulties which have preceded the successful issue of india-rubber insulation are precisely the same which were encountered for many years after the introduction of this substance as a branch of manufacture. Native or raw india-rubber, when in good condition, may be kept for years without sustaining any deterioration, but in certain stages of its manufacture it becomes susceptible of decay, which is accelerated by exposure to air and light. The decay of india-rubber is now well-known to be the result of oxidation, and is characterised by a gradual tendency to fluidity; its first stage of decay is recognised by a diminution of its elasticity, and by its becoming glutinous or sticky, and finally being reduced to a tarry-looking fluid, which state it always preserves.

The ultimate composition of india-rubber is represented by the formula C_8 H_7. The analysis of Dr. Miller accords, with tolerable exactness, with this formula—he found in 100 parts 85·82 carbon and 11·11 hydrogen. The sample which he analysed, however, contained 3·07 oxygen, and evidently could not have been pure caoutchouc. Neglecting the oxygen, the composition of pure caoutchouc, as reduced from its empirical formula (C_8 H_7), is 84·56 carbon, and 12·33 hydrogen, the difference in which from the results by Dr. Miller's analysis is practically nothing, and confirms the accuracy of the original analysis.

India-rubber in a manufactured state contains more or less of its oxidised product, which produces the colour recognised in this substance, pure caoutchouc being colourless. The word caoutchouc should properly be applied to that pure principle of carbon and hydrogen which forms the greater part of manufactured india-rubber.

The process by which india-rubber is rendered suitable for the purposes of insulation, consists of an operation which involves its partial oxidation, and unless this oxidation is arrested, the india-rubber becomes useless as a permanent insulator. India-rubber, when thoroughly washed, and dried, is masticated; by which means it becomes highly coloured, and is afterwards found to contain a variable amount of its oxidised product. By mastication, the india-rubber is converted into solid masses or blocks, which are cut up into slabs or sheets; the sheets are again cut into tapes, which is the only form for applying it to telegraphic conductors. The tapes being put on the wires, another operation is required to reduce them into a perfectly uniform and solid covering; this has been usually effected either by the use of solvents or the direct application of heat, both of which plans are seriously objectionable. By the application of solvents the india-rubber becomes more susceptible of oxidation, whilst the direct application of heat induces a molecular change more favourable to its oxidising. Wires insulated by either of these means indicate a very high state of insulation when first made, but as the india-rubber decays the insulation is reduced, and ultimately destroyed.

About two years ago five lengths of india-rubber insulated wires were supplied to the Government for submersion in the Persian Gulf, which, with the exception of one, have failed almost entirely. I was favoured with a report from Government a few weeks ago, made by Mr. F. C. Webb, from which it appears that the length remaining perfect is, at the temperature of 75° Fahr., three times better than the gutta-percha insulated wires which form the core of the Persian Gulf cable. Mr. Webb stated in his report that he did not know who were the respective manufacturers of these several lengths, but he brought home a piece cut from each length for identification. On my calling upon him, he placed the several pieces before me, and I had no difficulty in recognising my manufacture. Mr. Webb at once said that it was off the length which he had reported to the Government as being the only one that remained perfect. It will be seen from these numbers that it is the highest degree of insulation yet practically attained. A length of 1610 yards, tested under a pressure of 6000 lb. per square inch, and the same length, tested again under pressure of 4480 lb. per square inch, maintained for nearly eighty hours, showed an increase in its insulation resistance; and on removal of the pressure it was not found to have diminished, as has been stated to be the case with some specimens of India-rubber insulated wire. The length under this test contained two joints. The high results obtained from joints in my insulated wires have entirely removed all apprehensions on this important point; and there is no practical limit to the age of the material in which joints can be safely and reliably made. Five miles of my insulated wire, containing in each case eight and twelve joints, were uninterruptedly maintained at the temperature of 75° and 95° Fahr. respectively for 240 hours, and on being reduced to the initial temperature were found to have suffered no permanent change.

The facilities offered by my process for producing insulated wires of nearly identical degrees of insulation, and for reducing the most minute fault, enable me to bring forward this system as one by which absolute freedom from defects can be insured. This is a point intimately connected with the success of submarine telegraph cables; for it frequently has happened that minute faults have on submergence enlarged into sources of serious annoyance. The central position of the conductor is unaltered by any elevation of temperature; and, as it maintains a high degree of insulation at 150° Fahr., or even higher temperatures, it is peculiarly applicable for tropical seas. In its resistance to mechanical injury it far surpasses all other materials which have been tried for insulating telegraphic wires. The low inductive capacity of india-rubber renders it especially suitable for telegraphic cables, and by my process the low induction of india-rubber is maintained.

Sir Charles Bright, Mr. Latimer Clark, and Professor William Thomson have favoured me with the details of some very interesting investigations which they have gone through, on the qualities of my insulated wires; and, as Prof. Thomson was not aware that Sir Charles Bright and Mr. Latimer Clark were giving their attention to the subject, it is highly satisfactory to find how nearly they agree in reference to the inductive capacity compared with gutta-percha. Prof. William Thomson found the induction of my wire as compared with that of gutta-percha to be as 100 to 135, whilst Sir Charles Bright and Mr. Latimer Clark found it as 100 to 136. Mr. Wildman Whitehouse examined a length of one of my higher insulated wires, which he found as 100 to 160. As the rate of signalling is governed by the retardation arising from inductive charging, the transmission of messages will be inversely as these numbers, that is to say, that 135 to 160 messages could be sent through an Atlantic cable by using a conductor insulated with india-rubber according to my process, whereas 100 only could be sent in an equal time by using a conductor insulated with gutta-percha. This has a most important bearing in a financial point of view, since the cost of insulation by my method would not be greater, and in some of its forms considerably less, than that paid for insula by gutta-percha.

(Several lengths were shown to the sections, and also a diagram illustrating the effects of temperature as compared with gutta-percha.) The mathematical properties of the curve were, for the temperatures determined on my core, similar to those obtained with gutta-percha, but the differences in the insulation for increase of temperature were not so great as are observed to take place with gutta-percha.

The following table gives the insulation resistances in millions of B. A. units of my core and gutta percha, at different temperatures:—

	0° Cent.	24° Cent.	38° Cent.
Gutta-percha (Persian Gulf core)	3205	170	45
Mr. Hooper's core	71036	6328	2283

A length containing a joint that had been kept in a boiling solution of salt (220° F.) for twenty hours, was placed in a vessel to be again heated to that temperature and tested; but the committee decided that it was unnecessary to test it, or any of the specimens and joints exhibited.

The specimens and joints had been made at different periods during the last four years, and were shown for the purpose of

* Read before the British Association

being examined, to see that they had not suffered any change. Amongst the specimens was a length of half-a-mile with a joint, cut from the five miles referred to above.

During the discussion which ensued,

Mr. SIEMENS, F.R.S., expressed his concurrence with Mr. Hooper's remarks on the value of india-rubber insulation, as compared with that of gutta-percha, except that india-rubber improves in insulation under pressure; with that exception he considered Mr. Hooper had kept within, rather than gone beyond their relative properties. Difficulties had hitherto been found in the application of india-rubber as an insulator, and it would be interesting to the section to know how Mr. Hooper had overcome them.

Mr. FLEEMING JENKIN, F.R.S., stated that he had for some years been acquainted with Mr. Hooper's method of insulation by india-rubber, and he had never seen a length of his manufacture that indicated loss or decay. He considered the difference between the result of testing under pressure by Mr. Siemens and that by Mr. Hooper was caused by Mr. Hooper's process in consolidating the india-rubber; his experience tended to confirm the statements made by Mr. Hooper. He thought it exceedingly desirable that Mr. Hooper's cable should be practically tested by being submerged and worked, as it was evident that for long lengths and tropical seas it seemed to possess very valuable properties as compared with gutta-percha.

Mr. GASSIOT, F.R.S., said he thought the experiments in connection with the submergence of the two Atlantic cables had demonstrated that the two mechanical difficulties of the task could be overcome with a moderate degree of care and attention; and the most important consideration was that it had been demonstrated possible to lay a cable between Ireland and Newfoundland, but they must take care and not do as had been done in other cases, viz., lay down a cable which would only last two or three years. In this connection Mr. Gassiot pointed out the importance of the cable produced by Mr. Hooper, although he questioned if the time had arrived for a final experiment in the laying down and working of an Atlantic cable. He thought the bearing of india-rubber in its various qualities as an insulator ought to be satisfactorily and conclusively determined before the laying of another cable in the Atlantic was attempted. If they went on from year to year unsuccessfully, they would absorb any amount of capital; and the citizens to whom they must go for material support would close their purses; whereas, if they only waited the result of the experiments being diligently prosecuted by electricians, they would be able to come forward with a scheme which would not only be a success, but practically with the best cable. There would then be no difficulty in raising capital, for there was no doubt that the Atlantic Telegraph would be laid; but before again embarking on the enterprise every experiment should be made. This was the only prudent and safe course to adopt. He understood the Government had sent out, two or three years since, several lengths of insulated wire by different manufacturers to Kurrachee, including one by Mr. Hooper, to be practically tested by submersion in the Indian seas, and a report had been lately furnished to the Government stating that all of them except the length supplied by Mr. Hooper had failed; the report to Government went on to state that Mr. Hooper's cable tested three times better than the Persian Gulf cable, which is insulated with gutta-percha; the Government had, in consequence, given Mr. Hooper an order for about 50 miles of his cable, to be supplied forthwith. He considered the Atlantic Company might well follow the example set by the Government.

Waterloo and Whitehall Railway.—The works for the construction of this railway undertaking were recently commenced under the supervision of the engineers, Mr. T. W. Rammell and Sir C. Fox. The bed of the Thames on the Surrey side of the river, at a point nearly opposite College-wharf, and in a line with Scotland-yard, is being dredged for the foundations on which the iron tube is to be laid. At Scotland-yard the ground for the Whitehall station has been enclosed for the erection of the terminus on the north side of the Thames. From Scotland-yard the line will be carried in brickwork under the Thames Embankment to the river, through and across the bed of which it will be continued in a water-tight iron tube encased in cement. From the Thames the line will be continued in brickwork under College-street and Vine-street to the intended station on the north side of the Waterloo terminus of the South-Western Railway. Messrs. Samuda, of Poplar, are manufacturing the iron tube.

INSTITUTION OF CIVIL ENGINEERS.

Nov. 4.—The first meeting of the session 1865-6 was occupied by the reading of a paper on "*The Telegraph to India, and its extension to Australia and China,*" by Sir CHARLES TILSTON BRIGHT, M.P., M. Inst. C.E.

After referring to the previous attempts to establish telegraphic communication with India by the Red Sea, and alluding to the causes of the failure of that enterprise, the author proceeded to describe the steps taken by the Government to carry out the line through Mesopotamia and by the Persian Gulf to Kurrachee, which was now in daily operation, connecting England with Calcutta, Bombay, Madras, and all the principal towns of India, and extending as far to the eastward as Rangoon.

A description was given of the manufacture, laying, and electrical tests applied to the submarine cables between the head of the Persian Gulf, Bushire, Mussendom, Gwadur and Kurrachee, the engineering and electrical superintendence being carried out for the Indian Government by the author and his partner, Mr. Latimer Clark, M. Inst. C.E. The cables in question belonged to the class of shallow-water cables, the depth being generally about 40 fathoms, and the bottom being principally sand and soft mud, circumstances the most favourable for the deposition of submarine lines. The core was composed of 225 lb. of copper and 275 lb of gutta-percha per nautical mile, the gutta-percha being applied in four separate coatings; over this was laid a bedding of hemp, covered by twelve galvanised iron wires, the whole being coated with two layers of a compound of bitumen and silica, applied in a plastic state, in combination with two alternate servings of hemp laid in opposite directions. In the construction of the conductor four segmental pieces of copper within a copper tube were used, by which the mechanical advantages of a strand were preserved, while the electrical efficiency was added to, in consequence of the cylindrical form of the exterior.

The elaborate system of electrical tests taken during the construction and laying of the cable, and a series of experiments determining, for the first time, the differences of conductivity of gutta-percha and india-rubber at various temperatures, were fully described, a formula being given as a guide in calculating the effect of changes of temperature upon the insulation of submarine cables. A new method of testing the joints in the core separately was introduced, whereby a considerable gain in insulation was attained. The conductivity of the whole of the copper wire used was measured, and all wire below an established standard was rejected. By this means a high degree of conductivity was arrived at.

The total length manufactured was 1234 nautical miles, weighing in all 5028 tons. Five sailing vessels and one steamer conveyed this mass of submarine cable to Bombay, and the submersion was commenced by the author on the 3rd February, 1864, at Gwadur on the coast of Belochistan, the whole being completed by the middle of May in the same year. The cables were laid for the first time successfully from sailing vessels towed by steamers, by which a considerable saving was effected, compared with the cost of sending the cable round the Cape in steam vessels.

It was expected that the Turkish land line, between Bagdad and the head of the Gulf, would have been completed simultaneously with the submersion of the Persian Gulf line. In this, however, much disappointment was experienced, owing to the Arabs, on a portion of the route, in the valley of the Euphrates, being in revolt against the Turks. In consequence of this, the opening of the entire line between Europe and India was delayed until the end of February in the present year, when a telegram was received in London from Kurrachee in eight hours and a half. This was speedily followed by numerous commercial messages to and fro, and a large and remunerative traffic was now daily passing. The author, however, complained of the delays and errors arising upon the Turkish portion of the line, between Constantinople and Belgrade; the service on the portion of the line worked by the Indian Government, between India and the head of the Gulf, being performed rapidly and efficiently.

The difficulties encountered by Major Champain, R.E., in the construction of the Persian telegraph, between Teheran, Ispahan, Shiraz and Bushire, were described, and the loss of the late Colonel Patrick Stewart, R.E., and his devoted services, were feelingly alluded to.

In considering the extension of telegraphic communication from Rangoon to China and Australia, the author entered upon a narration of the advantages and otherwise of the several plans proposed; and considered, although part of the line in the Malay Peninsula, and elsewhere, might be taken by land, that the speediest and most reliable means of carrying the object into effect would be found in the submergence of submarine cables, if properly constructed and laid. The regularity of the working of a good system of cables would, in his opinion, soon compensate for the additional outlay involved over such sections of the line. It was thought that a line might be carried, in a comparatively short time, from Rangoon to Singapore, thence to Batavia, joining the Dutch land lines there, and passing from the south-eastern extremity of Java to Timor, onwards to the Australian coast, whither the Australian land lines were rapidly advancing, and would be erected to meet the cable. From Singapore a line could be carried to China, touching at Saigon, or the Peninsula might be crossed at Mergui, and the sea line be carried thence across the Gulf of Siam.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

The following Address by the President A. J. B. Beresford Hope, was delivered at the opening of the Session, November 6th, 1865:—

It is a relief to your president to feel that the address of 1865 follows upon a year of rest,—a year which, while it has not given birth to any particular reason for exultation, had, up to three weeks since, been equally devoid of any remarkable cause for sorrow and condolence. If there has been a Great Exhibition this year, it was one which was parted from us by St. George's Channel and the Race of Holyhead; and the exigencies of a huddled-up session, followed by a general election, have kept the collective wisdom of Parliament off from the fascinations of any art-crusade, or of any art-harray,—things which sometimes run somewhat closely up into each other. This lull, temporary as it may prove, may be used by us as an opportunity for reviewing calmly and fearlessly the position of this Royal Institute, as the general exponent and mouthpiece of English architecture, and for considering the condition of our national architecture itself, as it may be mended or the reverse, according as this Institute acts with unity, vigour, and wisdom.

I am ambitious for the honour and usefulness of the Institute, and as the result of this ambition, I decline to rest where we are. We are all doing our best, and yet the Institute, with its ample prerogatives, its royal charter, and royal medal, its powers of examination, and its various prizes, with the distinguished names that belong to it, and the vast mass of most interesting architectural lore which it has conveyed to the world, has not yet risen to the summit of its duties and of its pretensions. The Institute ought to be, without rival and without demur, the central regulating areopagus of architecture,—of architecture as a science, and architecture as an art; of architecture as practised by its professional votaries, and as studied by the amateur,—as loved by both,—throughout this imperial realm. The time should come when the absence of those letters which denote some grade in the Institute from the name of any one who practises architecture, should be as much cause for inquiry as the absence of academic distinction from that of the clergyman who has the misfortune to be a "literate." Do not mistake me, and imagine that I am the mouthpiece of any policy of aggression; least of all that I wish to crush the free art-life which has given birth to so many other architectural and semi-architectural societies, all instinct with the energy which the pure love of science and beauty inspires, and many of them further nerved up by the conviction of a mission to fulfil and a dogma to teach. I wish them all prosperity and all liberty. At the same time, I desire that they should all act as members of one system, moving harmoniously round one centre, co-operating as the volunteer forces of the great architectural army, looking up to this Institute, not as the tyrant whom they are pledged to bring low, but as the *Alma Mater*, ready to give all fostering care, at the cheap price of unsuspicious confidence.

We must not, however, shut our eyes to the difficulties attendant on the realisation of such an idea. I believe that in accepting it we should have to extend our borders, and to create one or more fresh classes of membership for the proficients in arts related to, but not identical with, architecture. This enlargement would of course entail increase of labour; but as it would involve increase of members also, more backs, no doubt, would be found broad enough and willing enough to bear the honourable burden. There is in particular and emphatically one phalanx which I earnestly desire to see absorbed into our body in larger proportions than they have as yet been. These are the architects who, because the buildings which they construct are pre-eminently massive, because they are buildings mainly devoted to the development of the grand material interests of the nation, because their measurement may be the furlong, and not the yard, therefore abjure the name of Architect, to borrow the incongruous appellation of Engineer. Do not mistake me, and imagine that one single thought derogatory to the grandeur of those constructions, or to the genius of the men who planned them, crosses my mind while I pen these sentences. The man would be unworthy of the name of Englishman who was not proud of them. All that I say is, that I demur to the appellation under which their constructors have produced them. What is an engineer? I look to Johnson, and he tells me: "Engineer; (1), one who manages engines; (2), one who directs the artillery of an army," with a reference to Shakspeare's engineer hoisted on his own petard. I seek further help from Richardson, but he only provides me with an illustration borrowed from South: "In like manner, as skilful an engineer as the devil is, he will never be able to play his engines to any purpose, unless he finds something to fasten them to." We all know, and we all admire, what our great civil engineers have done, and we lump all their grand works under one term, and call it "engineering." But it is surely just as incorrect to designate everything that Stephenson or Brunel accomplished engineering, as it would be to call all the works of Michelangelo architecture, or painting, or sculpture. Michelangelo was great in all constructive and plastic arts, but the versatility of his greatness did not bring those arts nearer together in themselves than they were before. So the patriarchs of modern engineering have mapped the roadways, invented the rolling stock, and designed the buildings, all of which in different ways go to make up a working railroad, just as an old architect might have built, painted, and carved a cathedral or public hall. The old architect thus showed himself to be architect, painter, and sculptor. So the civil engineer proved himself to be a surveyor in laying out the line; an engineer, properly so called, in constructing the engines; and an architect, in designing viaducts and stations. The name surveyor has no doubt gone out of fashion as applicable to the person who plans any very large works, and if the world prefers to substitute the designation engineer, I do not object. My immediate point is that the world should not continue to deceive itself with the belief that Stephenson and Brunel were not architects—self-made architects, it may be, just as the mathematician Wren and the physician Perrault were self-made architects, but, like those worthies of the seventeenth century, great architects. The notion that, because to them architecture came without the usual training, therefore the engineer is for the future to dispense with the trained and learned architect for the construction of buildings whose monumental elevation gives its colour to our age, is a wrong on our whole craft of architecture, against which it is right to make an earnest protest. But you will ask, what is this protest worth, and what is the practical remedy with which you wish to follow it up? How will you mend the state of things by inducing a number, more or fewer, of our civil engineers to join this Institute? Be assured that I propose no such trivial palliative. I wish the world, eager enough as it is in general for subdivision of labour, to see that in its creation of the new profession of civil engineer it has been false to its own principles, by overweighting the responsibilities of a calling which, growing as it has done with the growth of modern science, may be almost called a new discovery, with those of the old time-honoured one of architect. The mischief of this course is only making itself evident:—

"Decipit exemplar vitiis imitabile."

The great engineers overwhelmed us with the rough grandeur of their huge style; able but less eminent successors may but stifle us under the weight of heavy disproportion and unscholarly nakedness of detail.

The question of architect or engineer is not a mere fight of words. There are engineers who will build commendable structures, and architects whose works may be contemptible. But men's merits do not affect the value of principles. Architecture is the calling which, next to that of poet, dives deepest back into the young world's gulf of ages. As it moves on it spins out as part of itself that golden chain of association which ties together the ancient and the new, the foreign and the home-born, the beautiful and the useful. So an architect's education should be based on the broad foundation of history, science, and imagination. The liberal languages and the literature of other lands and times should be storehouses out of which he may bring the treasures with which he makes his handiwork lovable and true. Engineering repudiates the past, or uses it to point a self-exalting contrast. I do not say that engineers themselves do so; but this repudiation is the necessary price at which the constructive part of the engineer's business can any longer be formally divided from architecture.

It is not, then, more necessary for us to dare to speak the truth, and to believe that our engineering friends will bear to hear that truth. We attack no vested interests, we depreciate no living man's work, when we say that the vast monumental structures of this glorious nineteenth century ought pre-eminently to be designed by men who have, as architects, learned how past great architects grappled with bigness; men who have studied Egyptian Thebes and the Colosseum, the Pont du Gard, the Castle and Bridge of Avignon, Conway and Durham Minster. Let it be our office to revindicate for architecture all works of piled material, either containing chambers or else cast in architectural forms, whether they be of arched or trabeate construction. The engineer legitimately claims the level and the gradient, the earthwork, the roadway, the culvert, and the breakwater.

These considerations lead us to a topic which ought on its merits to be faced within the Institute,—the relation of the society with the Royal Academy. It is one of the questions which it is the fashion to call delicate; but I see nothing delicate about it, if it be handled in candour and good temper. I approach it in the spirit of the utmost good-will towards the Academy, although believing that I best show my good-will by declaring myself a believer in the desirability of certain reforms within that distinguished body, which I desire to see always filling the exalted position to which it has the means of doing justice, so long as it continues to realise that rank and wealth involve responsibility with corporations no less than with men. The dualism involved in a Royal Institute of Architects such as I have foreshadowed, alongside of a Royal Academy of Arts, including architecture, is, I freely grant, at first sight, puzzling; but I flatter myself that I see the way of reconciling with advantage to each other, and to pure architecture as well as to the mixed arts dependent on it, the continuous co-existence and the progressive development of the two great societies. Consider the broad differences which respectively mark off the constitutions of the two bodies. Both are, speaking generally, elective; but the election at the Academy means the choice of one distinguished man from out of many; while with us it is little more than the safeguard against improper nomination. Otherwise the Institute is in theory the collective body of all architects; the Academy a selected council of artists, among whom architects only form a certian, and I venture to add, too small a portion. But then, we may be told, let the number of architect academicians and associates be augmented, and then the Institute might be suppressed. Emphatically *no*. The Academy is a great advantage to architecture—what that advantage is I shall proceed to point out; but the Institute is a necessity. I have just been revindicating for architecture much which it is the fashion to call engineering; but this revindication strengthens the fact that, while architecture is an art, it is also what, for want of a better term, I must call a business or craft.* It is this perpetual combination of the *utile* and the *dulce*, the perpetual necessity of adapting style, ornament, and proportion to construction, and of so manipulating construction that it shall not sin against beauty of detail or mass, which makes architecture the peculiarly complicated and scientific thing which it is—an art, and something more than an art. It is this which makes it so fascinating to those who are really embraced by its spirit; while, on the other hand, it deters so many amateurs, who find it very much easier to set up as connoisseurs of painting and sculpture than to risk being discovered as incapable of apprehending the mechanical exigencies of building. Again, the architect has also, as a member of the commonwealth—charged with care for the life, health, and convenience of its various members—to make himself at home with sundry legal matters of which an academy of arts could have no cognizance, but which are the legitimate function of an architectural corporation.

Of this mixed craft and art, then, the Institute can be the efficient regulator, as the Royal Academy, a purely artistic body, cannot be. On the other hand, something like the Academy is just what is wanted for painting and sculpture; and being so for these two arts, it was seemly that it should also include architecture, otherwise the exclusion would have seemed like a denial of its claim to be a liberal art. Nay more, at the time when the Academy was founded, and architectural art in this country was passing through a time of great depression, I have no doubt that the step was eminently salutary. I proceed further, and say that even now, when architecture occupies in every way a very different position from what it did in the early times of George III., we are more likely to be the better than the worse for the Ephorship of the Academy. Still, it is well that we should know what the Academy can do and what it cannot. It cannot handle the many professional matters which constantly come before us. It can give lectures on the theory of architecture; it can teach a school of students on the art side of architecture; it can give prizes. We can also do all this, and we do a great deal of it. We shall do more when our School of Technical Teaching, on behalf of which a mixed committee was organised, gets fairly to work, as I trust it may do this session. Moreover, the Academy can, and does specially do, two things, neither of which we are so capable of carrying out. The first of them is not a part of its specially architectural functions, but it is of essential importance to the architect. The Academy possesses a life school, in which even the architectural student can acquire that power of drawing the live figure, which I am convinced ought for many reasons, direct and indirect, to form a portion of the *curriculum* of every one who desires to master architecture as an art, and not as a business.

The next thing which the Academy can and does do, is to hold an Exhibition. No doubt, if we had as large an income relatively as the Academy, we could hold our Exhibition; and no doubt, if the gallery in which we held it were one of the public buildings of London, we could make it a much better exponent of architecture than the Royal Academicians have ever made theirs. It would be affectation not to say, what we all feel, that the architectural portion of the great annual display fails in doing justice to architecture. The best evidence of the shortcomings of the Academy is to be found in the independent Architectural Exhibition, which has been carried on for several years with so much zeal, and has for a considerable time been held on the ground-floor of the building which lodges us. Still we must all confess that this independent Exhibition does not in itself completely fulfil the requirements involved in an annual London display of architectural progress. The reason is not far to seek, and it is no fault of the promoters of that exhibition. Imperfect as our representation in Trafalgar-square may be, it still stops the way; it has prestige and antiquity, and so, while defective in itself, it keeps the younger enterprise from filling the void. Accordingly we say, let the Royal Academy, while seeking a new habitation, bear in mind that it can win both honour and popularity by making its Architectural Exhibition each year a vigorous reality, alike for the general visitor and for the student. I am sure, if it embarked on this course, it would find no heartier co-operators anywhere than within the walls of this Institute.

In the evidence which I gave before the Commission which sat in 1863, to inquire into the condition of the Royal Academy, I urged its aggregating to itself associates out of the ranks of working artists. If it should take any such step, we, I am sure, in no spirit of rivalry, would also consider how we might enlarge our ranks, so as to admit the members of such professions into some regulated membership.

I have adduced instances of the peculiar work which we might wisely leave to the Academy. Let me now refer to two fields of labour of our own, in which we especially can do much good, but which would be quite beside the scope of the Academy. Air and light have an importance at once legal, sanitary, and architectural. That the Institute should have had a committee sitting on this question is a matter of unmixed congratulation. Only let me offer one caution—be not content with simply making a report, orce for all, on a matter which must be continuously watched through its many ramifications.

The conservation of ancient monuments, on which, also, we have a committee appointed, is happily a responsibility which is now universally recognised. But it is one thing to recognise and another to perform. A former generation destroyed without shame and without consciousness. Our present generation is too often in the habit of changing and spoiling and bedizening, and then of asserting with a complacent smile that it has only been restoring. Some of us have had our attention lately called to the painful fact that, with the very best intentions, the authorities of Lincoln Minster have lately been flaying alive the surface of that noble structure. Professor Willis, at the late Archæological Congress at Dorchester, laid down, in discoursing of Sherborne Minster, the true and exact law of treatment to which churches ought to be subjected—conservative alike of the fabric, and yet regardful of the solemnity and the exigencies of their still living use. The paper put out by our committee takes up the same position. Neither this paper nor the Professor handled the restoration of secular buildings; and so I hope we shall not pause midway, but instruct the committee to give the possessor of every castle, every hall and manor-house, and every grange, practical and straightforward advice how to live and let

* ...*ession* applies to the person who professes, and not to the thing professed, and ...erefore, serve my turn.

live, without damage either to his own health and comfort or to his archæological allegiance. No doubt this is a much more delicate problem than that of church conservation, where the fabric is either restored within its original unchanged walls, or else merely enlarged by aisle or transept, in accordance with the original *motif*; while house conservation is complicated by ever-varying necessities of family and social station, of ventilation, drainage, and smoke, for which no law can be laid down which can systematise the amount of necessary alteration; and therefore it is all the more necessary that some code of general principles should, if possible, be provided. The necessity has become more apparent, since, in an ever-increasing ratio, farm-houses situated in counties proximate to the capital or to chief towns, are snapped up if near railroads and turned into villas. These houses are frequently interesting specimens of Mediæval or seventeenth century architecture, sometimes perfect and sometimes disguised, which the judicious restorer would preserve and enlarge, while in the hands of the ignorant builder they would be doomed to hopeless destruction.

This sketch of the relations of the Institute to external powers would not be complete if I did not comment upon that ministry of Public Works which has gradually grown up out of the old office of Woods and Forests. It has from time to time been argued that, in order to avoid the vacillations and inconsistencies seemingly inherent in a fluctuating change of chiefs, there ought to be a permanent head of the Department of Works. I am decidedly opposed to any such arrangement. Not only is a permanent head to a great department antagonistic to our political instincts and traditions, but I believe that in this case the innovation would defeat its own object. The man who is originally appointed must have some art-notions or other of his own, or else he is palpably unfit to get the place at all. These notions may be good or they may be bad. Anyhow, if he is irremovable, they will be ineradicable, to the discomfiture of all opposing schools of thought. At best we should perpetuate sameness and tameness, at worst, ever-recurring clique and manœuvring. Besides, those who argue for the permanent chief, forget that in all public offices there is an element—often an overpowering one—of permanence in the irremovable second man. My own remedy would be based on the opposite principle, of exalting the attributes of the Minister of Works, treating his post as a necessary component, not merely of the administration, but of the cabinet, increasing his responsibilities, multiplying his inducements to do well, and withal hedging him round with such constitutional safeguards as a perpetual oversight by the Institute and the Academy, not to mention the still more severe and formal one of Parliament itself.

The Commissioner of Works is sometimes in the cabinet and sometimes not; and whether in or out of the cabinet he is in theory only a subordinate of the Treasury. This is plainly wrong, for it pulls down the importance of the office, and consequently checks young men who are going into public life from really studying art questions as a channel of political advancement, not much inferior, in its openings, to heavy statistics or colonial grievances. Then modern educational developments have accumulated a large amount of mutual responsibilities, more or less referable to architectural art and its cognate pursuits, between the State and the people, which, if imposed upon the Minister of Works, would fill the hands of the office and of himself, and justify the suggested increase of his dignity. But by some freak, the wise men who busied themselves a few years ago in re-arranging the public service, passed over the First Commissioner, and instead created an anomalous semi-minister, under the ambiguous name of Vice-President of the Committee of Council, to divide his time between high art at South Kensington and parochial school squabbles in general over the remaining kingdom. I give nothing but praise to the noble collection at South Kensington, while, at the same time, I say that its wants have no relation to the department of state under which it is placed; and I claim that this museum, with the appendant art-schools, would more congruously be made a function of the Minister of Works than of the Vice-President of Education. Let the departments be thus re-distributed, and the need for the latter never very well understood nor popular office falls to the ground. For the purpose of moving the really educational votes in the House of Commons, the Lord President himself, rid of his art responsibilities, would want, and ought to have, a parliamentary under-secretary, but that official need not be of weightier calibre than the Secretary of the Poor-Law Board. If the Minister of Works were expanded, as I propose he should be, into an undoubted and constant member of the cabinet, he should also have assigned to him a parliamentary under-secretary, to move estimates and make explanations; and then the Department of Works might be filled by a peer, if the fitting man turned up in the House of Lords. We should know how we stood towards such a minister, as we do not with respect to the actual First Commissioner. It would then be our duty, in conjunction with the Royal Academy, to see that, in the remodelling of the office, a definite standing should be given to those great societies, as the perpetual attorneys-general and referees of architecture at the bar of the administration. Thus the liability of the office-holder to be changed would check clique, and the fixity of his standing council would obviate fickleness and inexperience.

Let me now say a few words upon a detail of considerable importance to architecture,—the International Exhibition which it is proposed shall be held in Paris in 1867. Many here present to-night, no doubt, recollect the trouble that was taken in this Institute, and elsewhere, to secure an adequate recognition of architecture, as the great material symbol of civilisation, at the London Exhibition of 1862. The result was not all that could have been wished for; nevertheless, much was achieved on the British side,—the only side with which we had to do. Not only a highly interesting and overflowing gallery of architectural designs was furnished, but at various points of the ground-floor, notably in three special courts, and all up the nave, such large fragments of buildings in progress as were noteworthy by reason of form or detail, and even smaller buildings, like drinking fountains, in their integrity, were exhibited. Compendiously architecture, as architecture, made itself felt on the British side of the Exhibition, as it would not have done if the professors and the lovers of architecture had not in time bestirred themselves. I turned accordingly with anxiety to the prospectus of the French Exhibition, which has just been reprinted and circulated from South Kensington, to see if it indicated progress or retrogression since 1862, in respect of the due recognition of architecture as an elemental idea in the general arrangement. It is my duty to report that I am filled with grave apprehensions that, if that programme is to be acted upon, we shall find that recognition even less complete than it was in 1862. Of course, allowance must be made in reading this document for that love of playing at scientific arrangement which, among foreigners, sometimes tends towards something not very unlike pedantic fussiness. In one respect, I am glad to say that the Exhibition of 1867 is a marked improvement upon its predecessors; it will be truly universal, by breaking down the geographical divisions which converted its predecessors into what a man given to playing upon words might have called a map of the world upon Mercator's projection, and by ranging class against class in direct cosmopolitan competition. Here, however, I must pause in my praise, looking at the programme with an architectural eye. The prospectus ranges the exhibition in ten groups, subdivided into ninety-five classes. What an architect might have marshalled together under the great group of architecture is dotted up and down the list as follows:—Group 1 is entitled "Works of Art," and divided into five classes, of which No. 4 is headed, "Architectural Designs and Models," to be placed in the first gallery of the building, and is thus epitomised:—"Sketches and Details;" "Elevations and Plans of Buildings;" "Restorations based upon existing Views or Documents." I should have mentioned, that in a previous class, termed "Other Paintings and Drawings," occur, "Cartoons for Stained Glass and Frescoes," while there is another class of "Sculpture and Die-sinking," which may cover architectural sculpture, which has otherwise no distinct place. Class 9, in Group 2, introduces us to photographs of buildings. The third group is headed "Furniture and other objects for the use of Dwellings," and includes thirteen classes, which in their turn include a mass of miscellaneous articles, which it is difficult to image could not be better subdivided. The "Upholstery and decorative work" class starts with "Bed furniture and stuffed chairs," and closes with "Furniture, ornaments and decorations for the service of the church." The next class is designated "Crystal, Fancy Glass, and Stained Glass," and also runs from the secular to the sacred, from "drinking glasses" to "stained glass windows,"—the cartoons for such windows being, as we have seen, ever so many classes back. After exhausting other materials the classifier seems to have thought that the time for metal had arrived, and with a true system-monger's instinct he begins from the beginning with a class of "Cutlery—knives, penknives, scissors, razors, &c.—cutlery of every description," and goes on to recapitulate in subsequent classes "church plate, plate for the dining-table, and statues and bas-reliefs in bronze, cast-iron, zinc, &c." I am sure you will admire the philosophic rigour of the classification which ranges razors and bronze statuary side by side, and calls them both furniture. The anticlimax of the furniture group is a class of leather work and wicker. A long sweep brings us to the eightieth class, of "Civil engineering, public works, and architecture" (architecture you will note coming after civil engineering) in the large group of "apparatus and processes in the common arts," in which a miscellaneous catalogue tails off with "models, plans, drawings of public works, bridges, viaducts, aqueducts, drains, canal bridges, &c., lighthouses, and public buildings for special purposes"—as if there could be a public building without a special purpose;—"buildings for civil purposes; mansions and houses for letting; lodging-houses for the working classes, &c." I ask you, as men of common sense, if this elaborate catalogue, coming where it does, and contrasted with the vague generalities of the so-named architectural class in Group 1, does not indicate the subordination of pure architecture to so-called engineering! Another jump brings us to the last class but two, No. 93, which it seems is to be placed in the park, and is termed "Examples of dwellings characterised by cheapness, combined with the conditions necessary for health and comfort," and is divided into two heads: "examples for dwellings for families, suitable to the different classes of workmen in each country," and "Examples of dwellings suggested for factory hands in cities or in the country."

We shall be but guests at Paris, and so neither courtesy nor possibility allow us, I suppose, to make any formal opposition to a scheme already so elaborately prepared and officially published. We can only bear it and make the best of it. As your president I have the honour of being one of the British Commissioners, and I need hardly tell you that my most strenuous exertions shall be devoted to furthering the good cause of architecture. I should advise the formation here at as early a date as convenient of an exhibition committee. This committee ought to originate within the Institute; but, I think you will agree with me, that it might well contain an addition of co-operators from the cognate societies. If such were formed it would be my constant duty and pleasure to be the representative of its wishes at the commission. In any case, let every British architect, let every British architectural sculptor, metal-worker, wood-carver, glass-painter, and ceramist, gird himself up for a victory upon a foreign soil.

I must now offer a few remarks upon that which is even more important than the details of architectural administration; namely, the condition among us of that art in whose behalf alone this administration possesses any value. I am glad to be able to speak in a hopeful tone, and I am glad that the improvement which prompts that tone is one upon which I can insist without trenching on that impartiality which the position in which you have placed me demands. To whichever side the victory in the battle of styles may verge, this much is certain,—that the truth of architecture has been made more precious in our eyes, and her fertility of resources has been enhanced in consequence of the conflict. All sides are now agreed that material ought to be real, and all sides are anxious to enlarge the list of real materials. Variety of colour and variety of material in the same building has by this time become a question merely of degree. The sky-line is appreciated and studied; the catalogue of plants available for the working artist's chisel is no longer limited to the acanthus and the honeysuckle; finally,—the painter and the sculptor are, as in great old days, both of them welcome as brethren of the architect, and co-operators in the broad idea of the completed construction,—not merely as the parasites who are to fasten on the finished pile.

No doubt, with the single exception of the recognition of the sky line, the acceptance of these incidents does not amount to the demonstration of improvement in that which is of the chief importance in architectural art,—composition. It is possible to conceive the world's noblest design carried out in cement, while the vilest nightmare might be embodied in a façade of marble and serpentine, bristling with sculpture and bedaubed with gold mosaic. Yet, indirectly, the consciousness of variety in his materials, and in his permitted details, and the responsibility thus laid upon him to make his use of all, must strengthen the heart and heighten the intellect of the composer; for opportunities make men, as often, at least, as men make opportunities. As far, also, as truthfulness of material comes into question, a tender conscience in avoiding shams will also breed a manly truthfulness in the composition of the mass; for it is untrue to nature that the man who sees no vice in palming off plaster for stone and marble, and graining for oak, should be very scrupulous about the proportions of the mass, or the purity of his details, should he see a short and easy way open to vulgar popularity through the lavish employment of gaudy and meretricious forms.

If what I have said be true, we may expect to see the fullest proofs of the improvement in London and other large towns. Of the condition of London architecture, I am willing to think more favourably and anxious to speak more hopefully, than it is the fashion to do in some quarters. Undue depreciation is as little clever or original as undue laudation, while it is, if possible, even easier. No man is more conscious than I am of the infinite amount of lost opportunities which have to be made up in London, or of the ineffectual manner in which these opportunities have too often been taken in hand. But of late years, at all events, London has been shaping itself into that form of beauty of which alone, from many reasons, foremost of them our civil liberty, she is at present capable—the beauty, I mean, of picturesque variety. We know how, under different political circumstances, foreign cities are forfeiting their old picturesqueness in order to don the aspect of official regularity. London, on the other hand, is growing out of an irregularity of plan in which, speaking generally, there was no architectural character, into one in which irregularity has become picturesque. Of course, a vast number of the new London buildings will not stand criticism. But in which of the large old picturesque cities do we find the majority of the houses really good architectural composition? It is the ensemble, and not alone the merit of each component, which gives the general effect to cities such as Bruges or Amsterdam.

The first feeling of the stranger who comes unexpectedly upon the sumptuous palaces which are, for example, growing up in that dingy and narrow thoroughfare, Lombard-street, is probably regret that they should have been dropped down into a corner, which seems to preclude the appreciation of their merits. On second thoughts he may, however, pluck consolation from the reflection, that it was in narrow thoroughfares like Lombard-street that the buildings which give their fame to cities such as Verona or Genoa were planted; and that the picturesqueness which the traveller finds to admire in them is in no little degree enhanced, whether truly or in imagination I do not now concern myself to ask, by the narrowness and irregularity of the ancient streets of these cities. Perhaps in coming time, when London shall house by house have been rebuilt, as we are now rebuilding it, and when a little of the mellowing of time shall have passed over those buildings, the curious traveller from the antipodes may visit London, not to sit upon the broken arch of London Bridge, but to drink in notions of Old World picturesqueness from the houses of Lombard-street and Mincing-lane.

In what I have been saying I have confined myself mainly to the development of domestic architecture upon existing lines of streets. If, for example, I were to speculate upon the razzias and rebuildings which follow on the importation of railroad termini into the heart of the town, I should engage you in a maze of conjecture of which I feel that I have no time to seek the clue. The architectural future of the Thames Quay is a problem which ought to fill us with anxiety: the material advantage of the great enterprise is beyond a peradventure; the artistic gain which may be made of it remains to be gauged. It is a curious reminiscence that when the Thames quay was first advocated in the House of Commons some forty years ago by Sir Frederick Trench—a name to be always had in honour for the courageous and constant zeal with which its possessor continued to advocate an improvement which he was not destined to see completed—it should have been opposed by Sir Robert Peel, in the interest of the streets running down to the Thames, and supported by Lord Palmerston. Were I to enter upon the new phase through which religious art is passing in London, as well as elsewhere, I should have still more to say, which, however, I think it is better not to say. Were I further to talk of that feeling of respect for the ancient monuments of the metropolis which has prompted so general a restoration of them, my anticipation of London's architectural worth would be still further enhanced. The epoch which witnesses simultaneously the decoration of St.

Paul's, of Westminster Abbey, and of the under-croft of St. Stephen's Chapel, the restoration of the Tower, and Guildhall, of the Temple, Austin-friars, and St. Bartholomew's Churches, and the Savoy Chapel, and the resurrection of Charing Cross, is one in which the spirit of reverence for old forms of beauty must be abroad.

Next year the Archæological Institute holds its congress in London. It is well that we should be able to meet it with a confident spirit in a city which has not been untrue to its inheritance of ancient buildings. The pursuits of this society are to a great extent parallel with our own, and I am sure we shall cordially welcome a gathering of which a main object is the complete investigation of the monuments of architectural antiquity in and around London.

I have been the more anxious to invite your attention to the architectural condition of London, because next session will in all probability decide whether the capital is to be enriched with a great public building of undoubted excellence, or afflicted with one of costly mediocrity. The nation is going to rebuild its Law Courts, and mass them in one pile. I do not now question the site selected. This is, according to the modern phrase, an accomplished fact; and it is enough to say that the area chosen is one well suited for a magnificent and commodious structure. I say nothing, though I might say much, about the method to be adopted in selecting the architect. I do not claim to dictate the style, for I trust that, whatever style may be chosen, architectural truth may not be sacrificed. If the building is to be Classical, Classical must not be interpreted to mean a modern house, with floors below, and chimney pots above, ill concealed by barricades of pillars, fencing off light and air from the unhappy occupants. If it is to be Gothic, Gothic must not be handled as the style which enforces narrow casements and diamond panes, turrets that lead to nowhere, and gurgoyles that spout no water. Under any conditions, we claim a building which shall tell the tale of its own destination, and indicate the puissance of the nation in whose behalf it has been raised. We claim—what Manchester, out of merely a county's resources, has so generously provided—a palace in which the disposition of parts and the ornamentation spring from the destined use; in which the law courts and the great hall shall stand out from the general structure; in which the corridors shall be lofty and wide, the staircases easy and dignified, the subsidiary chambers many and accessible; acoustics, light and warmth, and ventilation, all well attended to; and after all these utilitarian requirements have been satisfied, in which proportion and material shall be of the choicest; in which form and colour, sculpture and painting, shall combine to beautify the pile, and leave it a living chronicle of the great growth of that sublime spectacle, the world's wonder and envy—English law, fearlessly and solemnly administered by English judges, without spite and without favour, unbiassed by Crown, or mob, or armed battalion. If the building shall fall short of this ideal, great will be the scandal and the misfortune on whomsoever's back may lie the blame of the miscarriage.

If it were only for the proximate erection of the Palace of Justice, next season would be an important one to us. But in this age of changeful activity it is not needful to look to any one incident as the text on which to preach more vigilance, greater exertion. We are all proud of our Institute; we all acknowledge its importance; we are all conscious of what it has done, and of what it might do which it has not done. Let all of us, then, laying aside self-seeking and mutual jealousy, sloth, and fear, unite with one heart, cheerfully and magnanimously to promote the best interests of architecture as a science and as an art, and to build up this Institute as a guarantee to ourselves and to the world that architects shall respect and the public acknowledge the just claims and genuine character of that science and that art.

ON SUGAR-MAKING MACHINERY.

By Perry F. Nursey.

(*Concluded from page 341.*)

Such, then, is the apparatus required in the extraction of the juice from the cane, comprising in brief, a 16-horsepower steam engine, and a 20-feet Cornish boiler. Manufacturers, of course, vary in their details of construction, but the general features remain the same, this being found the most efficient and practical arrangement. The method of working is as follows:—The canes are introduced between the rollers from the feeding table, and are crushed between the top and the first bottom rollers. Guided by the trash turner they pass to the top and the second bottom rollers, between which the juice is expressed, and the fully-crushed cane or megass is delivered away by the delivery table. Care is taken that the expressed spongy cane does not again come into contact with the juice to re-absorb it. It is of importance that the rollers should revolve slowly. The result of repeated experiments has shown that, with a speed of 8 revolutions per minute, only 46 per cent. of juice has been obtained, but, by reducing the speed of the same mill to 2½ revolutions per minute, 70 per cent. of juice was obtained. The velocity of the rollers should be rendered as uniform as possible, not by diminishing the amount of the motive power, but by a carefully regulated supply of canes in the feeding. The absolute amount of work done, however, materially depends upon the quality of the cane. A fair working result from a 16-horsepower mill and apparatus would be between 5 and 6 tons of cane per day of twelve hours. Some years ago a method was patented by Mr. Michiel for extracting the sugar from the cane without the use of the mill. It was proposed to cut the canes into thin slices, and treat them with lime water. The object of this was to render the nitrogenous constituents of the cane insoluble. On treating the canes thus prepared with water, a syrup is obtained of a purity much greater than possessed by that obtained directly by mechanical means. Probably the mechanical difficulty experienced in slicing the canes has prevented the adoption of this method. Captain Margetson, R.N., has proposed to cut the cane in pieces, and dry it as beetroot is dried, sending the substance home for the extraction of the sugar. It might be worth while experimenting in this direction.

III.—*Purification and Concentration of the Syrup.*

The juice, on being delivered from the mill, is full of impurities, the removal of which may be divided into two processes—defacation and clarification. In defacating the syrup lime is the agent most frequently employed; but there are wide differences of opinion as to the best method of its application. The lime should be thoroughly burned, and quickly slaked with hot water, enough water being added to give the consistence of cream. This should then be filtered through a fine wire sieve, in order to remove silicious particles and fragments of unslaked lime or unburned limestone. The following process is adopted by some manufacturers:—When the syrup in the clarifiers has attained the temperature of 130° Fahr., successive portions of the cream of lime are added until the acids in the syrup—acetic and lactic—have been completely and exactly neutralised, which is shown by litmus paper. The mixture of syrup and lime is thoroughly incorporated, and left to digest for about a minute. The cream of lime added to effect neutrality should not contain more than about four ounces of solid lime per gallon. The product so obtained is run off, through a stopcock in the clarifier, to the bag or charcoal filters to be noticed presently. In the more common process of defacation, after neutralisation by cream of lime, as above described, the heat is urged until a temperature just below the boiling point of the syrup is reached. A thick scum is then formed upon the surface of the syrup, and the clarification is judged complete when this scum breaks, and a white froth appears in its interstices. In all cases an excess of lime is to be guarded against, mainly on account of the destructive action of caustic earths on sugar. Various other substances have been employed for the defacation of cane juice, the principal of which are—bullocks' blood, nut galls, sulphate of zinc, alum, sulphate of alumina, sulphuric acid and lime, and subacetate of lead.

In one process of clarification the juice, as it is expressed from the cane, is run into the clarifiers and a battery of pans. The clarifiers are copper pans with arched bottoms, into which the juice from the cane is conveyed. From these pans it is run into the battery. These pans or teaches are also of copper. As the juice becomes concentrated, each pan is filled up from the one next behind it, until the striking teach is full of granulated sugar, which is then ladled into shallow wooden vessels and conveyed to the curing house. An improvement upon the old system of ladling is now much used. It consists of a copper pan or dipper, fitting the inside of the striking teach, and having at the bottom a large valve, opening upwards and worked by a lever. The dipper is attached to a crane which commands the striking teach, and a gutter to the coolers. This implement enables the striking teach to be emptied and refilled in much less time than by the ladle. The pans are set in brickwork, with a furnace under the striking teach, and a flue through which the heat passes under the range and under the clarifiers to the chimney. The megass from the cane mill is dried and used as fuel for the battery, being much better suited for that purpose than any other convenient fuel, as far as heat goes, a quick fire being required. By placing the boiler of the cane mill at the end of the battery, so that the products of combustion may pass from the latter to the former, a saving of fuel is effected.

In another and improved method of clarification the necessary heat is obtained by steam. This is a great improvement, and by its adoption the process of manufacture is facilitated, and the colour and quality of the grain are improved. It is more economical in the working, and admits of more perfect regulation of temperature.

The steam evaporator consists of a rectangular wrought-iron vessel or tank, at the bottom of which is placed a range of copper pipes, connected by gun-metal bends brazed to the pipes and carried on wrought-iron supports. The tank is fitted at the side with a steam valve at one end of the steam range, and at the other side is a cast-iron box fitted with a wrought-iron pipe for exit of condense water to condense box. This form of evaporator presents a large amount of heating surface, with facility for cleaning. By passing the ends of the steam range through stuffing-boxes the pipes can be turned up, and all parts of the evaporator readily cleaned. This is a point of great importance in the manufacture.

The clarified juice or liquor after leaving the clarifiers is passed through mechanical filters. The kind commonly used are bag filters, which consist of a wrought-iron case, provided with openings, and made with an internal flange at top to carry a cast-iron box, having holes at the bottom, into which are screwed gun-metal bells, to which the cotton filter-bags are attached. Each filter is fitted with a stopcock at bottom to the copper main. A steam cock is attached to the side of the wrought-iron case, for cleansing the filter by the admission of steam. The bags which are attached to the bells are made of twilled cotton cloth, and are about 6 feet in circumference and 6 feet long, woven without a seam. They are enclosed in a strong open webbing about 18 inches in circumference, thus giving a large surface of filtering medium in a small space.

The charcoal filters are large slightly conical vessels, generally of wrought-iron, with a perforated false bottom about 1½ inch from the bottom. A blanket is spread over the false bottom, to prevent the charcoal from being carried through with the liquor; some, however, always accompanies the liquor at first, which runs into a separate receiver to be filtered over again. In filling these vessels the first few inches of charcoal should be pressed compactly down, after which it is packed lightly, but evenly, nearly to the top, where space is left to receive the liquor. The object to be attained in these filters is to remove all the vegetable colouring matter from the liquor, and any excess of lime that may have been added during the clarification, as well as some of the mineral salts, such as sulphate of lime, originally existing in the cane juice.

IV.—*Granulation, or Crystallisation.*

The granulating is performed *in vacuo*, so that next in order for consideration comes the vacuum pan, which depends for its action upon the principle, that liquids boil at greatly reduced temperatures when relieved from the pressure of the atmosphere. The vacuum pan, originally patented by Howard in 1812, has been of great value in the chemical arts, not only in the preparation of sugar, but also of medicinal extracts and other substances. It has, however, gone through a variety of improvements since the date of its introduction. The vacuum pan apparatus consists of a vacuum pan, which is mounted on a cast-iron framing, carried by eight cast-iron columns. The top compartments of the framing are fitted in with deal boarding or iron plates, which form a staging round the vacuum pan. The pan is fitted with thermometer, vacuum gauge, sight glasses, proof-stick for extracting samples of sugar, slide for discharging sugar from pan and for steaming, &c., steaming cock, in connection with a steam pipe, to admit the steam to clean out the pan. There is also an arm pipe, and a receiver to catch any sugar that may boil over. The receiver is fitted with a delivery cock, and air cock for destroying the vacuum when necessary. The condenser is fitted with a perforated pipe and a stopcock, with a lever and an index plate to regulate the supply of water for condensing the vapour from the vacuum pan. There is a measure for regulating the supply of sugar to the vacuum pan. The measure is fitted with a stopcock and inlet pipe from the filtered juice tank, a glass gauge to indicate the quantity of syrup in the measure, outlet pipe, with a stopcock opening into the vacuum pan, and an air pipe having a cock communicating with the vacuum pan, for forming a vacuum in the measure. A valve is attached for the supply of steam from the expansion vessel to the worm of the vacuum pan; and a pipe for carrying off condensed water from the steam coil or worm of the vacuum pan to a condense box, which communicates by a pipe with a brick tank, from which the feed water is supplied to the boiler An air valve is mounted on an air main, for regulating the communication between the air pump and the vacuum pan. There is a dividing box for distributing the flow of air from the vacuum pan to the air pumps. There are two 16-inch air pumps. 1 ft. 9 in. stroke, and a 10-horse power high-pressure beam engine, fitted on diagonal frames, with 11 inch cylinder, 3 ft. 6 in. stroke, and 12 feet diameter fly-wheel, with 6 inch elliptic rim; 4 inch plunger feed pump, with stopcock, clack box, copper air vessel, and feed-water supply pipe to boiler, fitted with safety valve, weighted for regulating pressure on pipe and stop valve to boiler. The Cornish boiler is 36 feet long and 6 feet diameter, and is made in two parts for facility of exportation; it is put together with wrought-iron rings, and is fitted with gauge cocks, mercurial pressure gauge, safety valve, whistle valve, and steam chess, mounted with 5 inch steam valve to pipes for supply of steam to the engine, and to the vacuum pan through the expansion vessel. A sluice cock regulates the supply of steam to the mercurial regulating valve, by which the supply of steam is regulated to the expansion vessel, which is fitted with a whistle valve and safety valve to prevent excess of pressure in the worm of the vacuum pan; the steam passes from the expansion vessel through a pipe to the steam valve which regulates its admission to the vacuum pan.

A vacuum pan 7 feet in diameter—that being the size suitable for the rest of the machinery—consists of the copper pan, fitted in a cast-iron steam case, with steam space left between the two; the pan is surmounted by a copper dome. The copper and iron pans and the domes, are accurately fitted and bolted together through their flanges with a wrought-iron ring and bolts, as in the case of the clarifier, so as to be perfectly air and steam tight throughout. A manhole, with a ground gun-metal cover, is attached to the top of the dome, from which proceeds the arm-pipe, opening into the receiver; a steam valve is attached, which opens into the copper steam worm. This worm gradually diminishes in diameter from the entrance point at the steam valve to the exit at the bottom of the pan. A wrought-iron pipe is fitted into the cast-iron pan, to carry off the water to the condense box. A slide valve is provided at the bottom of the pan for discharginn the sugar; the dome of the pan is mounted with a vacuum gauge, thermometer, sight-glass, and proof-stick, for testing the concentration of the liquor without destroying the vacuum in the pan. This proof-stick is simply a brass rod, which is driven from the upper part of the side of the vacuum pan down an aperture made of the same size as the rod. When it reaches the bottom the rod is twisted half round by the cross handle, and opens a communication with the end of the rod and the syrup. In the end of the rod is a groove into which the sugar enters; the rod is half turned again and drawn out, and the entrance is closed as before.

In situations where there is not sufficient water to admit of condensation by injection being used, surface condensation is employed to maintain a vacuum in the pan. For this purpose, Messrs. Pontifex and Wood use condensers, which consist of one or more series of iron or copper pipes fixed to boxes at each end, with partitions to direct the current of the vapour. Above each series of pipes is fixed a trough, always kept full of water, and so constructed that the water trickles in a gentle shower uniformly spread over the pipes, so as to keep them well covered with a thin film of water. The lowest pipe is connected with a small pump, worked by the engine, which draws the condensed vapour, and any air that may have collected, from the pan. An improvement introduced by Messrs. Pontifex consists in doing away with solder joints at the junction of the pipes with the case, the solder being liable to crack from the unequal expansion of the pipes (owing to the lower pipes being cooler than the upper ones), and the substitution of an elastic joint, which allows for the irregularity of the expansions without injuring the vacuum; they are also easily replaced, not requiring any mechanical skill, and take up less space for shipment. The superior economy of water in these condensers is owing to the condensing water being evaporated, and carrying away not merely sensible but latent heat. The ordinary method of condensation is similar to that employed in the condensers of steam engines, when the steam is led into a vessel where it is brought into contact with a stream of cold water. In this case, as the condensing water must not be allowed to become vaporised, all the heat it absorbs must be in the form of sensible heat, and it is said practically to require about thirty times the quantity of condensing water. But in these surface condensers the vapour which passes off from the surface of the pipes not only carries off the sensible heat, but it also renders latent a great amount of heat in its conversion into vapour, the quantity of water passing off from the surface being equal, or nearly so, to the quantity condensed inside the pipes. The water which falls into the trough under the condenser is used over again, the heat of it not materially affecting the action of the condensers.

The mercurial steam regulating valve of Messrs. Pontifex and Wood consists of a cylindrical casting, having an internal cylinder, passages, and a 3-inch flange branch, cast in one piece; it is fitted with cover and fastenings. The internal cylinder is 4 inches diameter, and is bored out for the reception of the gun-metal cylinder, which must be accurately fitted in place, having passages cast in it corresponding with those in the cast-iron cylinder for the admission of high-pressure steam. A gun-metal cylindrical slide is turned and fitted to the gun-metal cylinder, and is attached to a float by means of a crosshead. A wrought-iron mercury tube is fitted with a cast-iron box. The apparatus is provided with a flange for connection to the 4-inch pipe, to conduct the reduced steam to the expansion vessel. The reduced pressure steam (18-lb.) required in the vacuum pan, clarifiers, &c., is obtained from the ordinary boiler steam (40-lb.) by its action on the mercury. According to the rise or fall of the mercury in the cylinder and tube, so does the float rise or fall, and thus opens or shuts the passages, according to the pressure of steam on the larger surface of mercury, which pressure is regulated by the height of the column of mercury in the tube. The duty of the box is to receive any mercury that may be forced out of the tube by the steam pressure in the cylinder, and it is returned through the aperture in the tube.

It will be observed that copper enters very largely into the composition of sugar machinery. Such being the case, and considering the character of the metal, it may be useful to give the weights and thicknesses generally adopted in the various portions of the apparatus. These are as follows:—Thickness of dome of vacuum pan, ¼-inch in rim and ⅜-inch at centre; the same thicknesses apply to the bottom of the pan; each weighs about 8 cwt. 2 qr. 14 lb. The metal in the worm of the vacuum pan is ¼-inch thick, that in the arm pipe 3-16 inch thick, and that in the measure 3-32-inch thick. The clarifiers are ¼-inch thick on the rim, and ⅜-inch at centre, and each weighs about 6 cwt. The light course of the clarifiers is ¼-inch thick; the open clarifiers and battery of pans or teaches, are ½-inch thick at bottom, and ¼-inch at top. The copper troughs are 1-16-inch thick; copper main to the bag filters, ⅛-inch; copper pipes in the evaporator, ¼-inch thick; copper pipes in *monte-jus*, 3-16-inch; copper main to charcoal filters, 3-16-inch thick; the air vessel to the pumps, 1-16-inch; and the float for the condense-water box, 1-32-inch thick.

The following is an estimate for a set of apparatus as usually supplied to work with a 16-horse power sugar mill, and is sufficient to take the full produce of juice from that sized mill when working at its best. The prices are for the goods packed and delivered at the works:—

Estimate.

	£	s.	d.
One 16-horsepower cane mill, pump for raising liquor, three spur pinions to connect rolls, intermediate gearing; one high-pressure 16-horsepower horizontal engine and fly-wheel; one Cornish boiler, 20 feet long, 6 feet diameter, and 3 feet flue, fitted and mounted complete; the whole, including all necessary bolts, &c., complete for fixing	1450	0	0
One cast-iron staging, supported on columns, to receive the vacuum pan, with flooring plates, hand rail and stairs, and with air pumps, engines, &c.	1913	0	0
Carried forward ...	£3363	0	0
Brought forward ...	£3363	0	0
One 7 feet inside diameter, strong and highly-finished copper vacuum pan, with large copper worm, steam branch direct into jacket, gun-metal steam and air valves, copper measure, copper safety receiver with arm pipe, cast-iron condenser, with gun-metal dial cock and copper injection pipes, two condense water boxes, glass gauges, barometer, thermometer, proof-stick, &c., complete			
Six strong copper steam clarifiers 5 feet diameter, with cast-iron steam jackets, gun-metal steam valves and two-way cocks, two copper channels, and copper pipes from discharge cocks	895	0	0
Four wrought-iron bag filters of 60 bags each, with gun metal draw-off cocks, steam cocks, copper main, &c., and one set of bags to each	380	0	0
One wrought-iron evaporating or clear liquor heating cistern, with copper steam coils, gun-metal valve, discharge cock, &c.	65	0	0
One wrought-iron *monte-jus*, with gun-metal cocks, copper pipes, &c.	80	0	0
Eight wrought-iron charcoal fitters, stopcocks, &c., copper mains, cocks, &c.	410	0	0
Ten wrought-iron store water tanks, pipes, cocks, &c., steam pipes to all vessels, and sundries	470	0	0
Two 30-feet Cornish boilers, mounted, complete	500	0	0
Two open copper clarifiers of 600 imperial gallons each, with discharge cocks, &c., and four open copper pans or teaches of 200, 300, 400, and 600 gallons contents respectively	598	0	0
Total cost ...	£6761	0	0

The above estimate may be taken in round figures at £7000. As will be seen, this does not include Messrs. Pontifex's surface condensers, which if employed add about £600 to the above sum.

Machinery and apparatus such as have been described, and fitted with all the modern improvements, are, it is true, costly in erection; but they very soon pay for themselves, in the superior quality of the article produced, and the greater return for the same quantity of canes. By employing the strong mills and powerful engines as now manufactured, the canes yield a much larger percentage of juice than previously; and the megass leaving the mill being much drier, is in a better condition to be used as fuel. By applying steam heat and boiling *in vacuo* at low temperatures, the colour is improved, and less of the sugar is converted into molasses; so that estates which were formerly worked at a loss may, by the introduction of improved machinery and utensils, be made to yield a profitable return.

V.—*Improvements.*

A long account might be given of the numerous interesting and curious attempts at improvement in all the various processes of sugar manufacture; but there are two reasons why no detailed statement will be here made of the alterations—otherwise called improvements—which have been proposed from time to time. The first is, that an outline description of them would occupy an evening, and would be out of place in a paper; and the second is, that no practical purpose would be served thereby. It will therefore be sufficient to refer to such improvements as have come under the author's notice, and justify a reference by their practical character. In the arrangement of the mill-gearing, Mr. N. P. Burgh, the author of a very practical work on sugar machinery, makes a girder-like frame, or in section as the letter U inverted, the engine used being horizontal. The first motion shaft is on a line with the crank shaft, and the second motion shaft is supported by two plummer blocks, one of which is secured to the engine bed-plate, and the other on the main framing. He argues that a greater stability is obtained by surrounding the gearing with a framing than by any other means. The disconnecting gear is somewhat novel; instead of the square coupling or the disc coupling, a socket is preferred, the shafts of both spur wheels and top roll being fitted with four keys, the socket being made to slide on these keys; corrugations are cast and turned on the surface of the sockets, and by a small spur pinion working into these corrugations, a rotary motion being given to the pinion, the socket slides forward or backward as required. An improvement on the adjustment of the cane returner is attained by double wedges at each end of the returner, the smaller end of each wedge being screwed; adjustment is produced by turning a nut on each wedge. With reference to vacuum pans it is to be observed that, in most cases, the stop valve of the condenser is secured on the outside in a separate case. Mr. Burgh, however, inserts the valve in the connecting pipe, at the bottom of the condenser. Motion is imparted to the valve by a lever outside the condenser, the connecting rod being inside. By this arrangement simplicity and direct action are attained; also when the valve is closed the water in the condenser assists to render it tight. When the valve is open the water can pass direct from the condenser, while in the ordinary mode the exit must be made at right angles, thus increasing the friction, and reducing the vacuum. For creating a vacuum, double-acting horizontal pumps are preferred to the single-acting vertical type, which have to be entirely disarranged for inspecting the foot valves. As the steam cylinder is between the pump and the fly-wheel, and as each set of valves can be inspected by separate doors, simplicity and economy result, and a better vacuum can be maintained.

The use of steam in sugar houses, whether for colonial or home produce, has now become general, and its economical use is a matter of the first importance. Steam at a given pressure occupies a certain space, and creates a given temperature; hence, in all modern sugar factories the use of the expansion valve is considered imperative. These valves are of various kinds; lever action and spring and weight balances are the most general. Stuffing-boxes create friction, and in the case of the expansion valve the action of the steam causes the reduction of pressure. Now, if the spindle of the valve and the valve itself be acted on by the stuffing-box and the steam a great inequality of action will be the result; valves so arranged require the most critical adjustment. In order to mitigate these evils, Mr. Burgh has effected an arrangement whereby stuffing boxes are dispensed with, and the action of the steam on the valves is rendered nearly neutral. The form of valve used is of the double-beat type; a piston is connected to the valve by rods, and on the steam entering the casing it passes through and around the valve, and, before its exit, operates on the piston, the latter being regulated by a spiral spring at the back. Hence rods, valves, and piston are within the casing, and the only friction imposed is beyond the steam, and is due to the metallic rings in the piston.

The next improvement will be the "Bour evaporating pan," so named after the inventor, Mr. Bour. While observing the working of the Wetzel pans, he found that larger grains of sugar were produced at the discs at the ends than in the middle, where the breaking up motions of the tubes disturbed the formation of the crystals. He then concluded that to dispense with the tubes and make a series of discs over the whole length of the pan would give better grains of sugar all over, and also have a greater amount of heating surface. These pans are now getting well into use in sugar-growing countries, as a very good sugar can be made in them by the ordinary attendants on the estate. The patent has become the property of Messrs. D. Cook and Co., of Glasgow, who appear to be successfully working it. The Bour pan consists of ten hollow discs of copper, mounted on an axis of a form which allows the steam to communicate freely with all the discs, and at the same time, collects the water resulting from the condensation, and carries it off at one end. In the inside of each disc are two spoons, running from the extreme diameter of the disc, and terminating in the axis into which the water is delivered. On the outside of these discs are a number of small buckets, which lift the liquor as the discs move round, and which, being open at the sides, admits of spreading itself as a thin film over the surface not immersed, which is remarkably favourable for rapid evaporation. Where the Bour pan is used the number of pans in the battery may be reduced, in some cases only three pans being used, and the finishing completed in the Bour pan, without any risk of carbonising the sugar, from the ease with which the steam can be regulated to the heat wanted. The speed of the revolver may be from 10 to 20 revolutions per minute. Where steam is plentiful, equally good sugar is produced by the quick speed, and nearly double the work performed in the same time. In an estate in Penang one of these pans has cooked 12 cwt. of sugar per hour, from 20° Beaumé, as taken from the battery, the temperature never exceeding 170° Fahr. The pan may be driven by a small engine, the exhaust steam of which is carried through the pan, or by any convenient arrangement from any other source of power. The exhaust steam from an engine is that generally employed, but direct steam from the boiler through a small pipe may be used, with a regulating cock attached. A safety valve is fixed on the top of the column where the steam enters, which blows off at 2 lb. per square inch; this prevents bursting from over pressure.

We now pass on to notice the valuable invention of Mr. Alfred Fryer, of Manchester (of the firm of Fryer, Benson, and Forster). It is called the concretor, and its object is the more rapid condensation of the syrup. The machine consists of three principal parts—a tray, a cylinder, and a drum. The tray is placed as close as possible to the sugar mill, and receives the juice direct from the rollers. It is of cast-iron, 3 feet long by 6 feet wide, and 6 inches deep. It is crossed by ribs or ledges, which run from one side nearly to the other, the vacant spaces being on alternate sides of the tray. It is cast in several lengths, which fit into each other; and should any length be injured it may easily be removed and replaced by a new one. This tray is set up at a gentle slope, so that the juice received at its upper end flows in a continuous stream, not more than about ½-inch deep, backwards and forwards, from side to side, to the lower end; the whole length of the passage in the machine itself is 140 yards. Underneath the tray is the furnace, the flame of which spreads evenly along the bottom in a broad sheet, the draught being perfectly clear and uninterrupted. The time occupied in the passage of the juice through the tray is about five minutes, in which short period eleven-sixteenths of the water are driven off, and the juice has already become what is termed "sling."

On leaving the tray the liquor is passed at once into the second part of the machine, called the cylinder. This is of copper, 20 feet long and 3 ft. 6 in. in diameter, and it is kept slowly turning about six revolutions per minute, by a small engine attached for the purpose. The cylinder is partially open at the end, only a narrow ledge being left, retaining a shallow quantity of the liquor in the lowest part, from which the constant revolution of the cylinder carries up a thin pellicle or film of syrup. The outside of the cylinder is heated by waste heat from the tray or its furnace, or both. Through the inside of the cylinder a blast of strongly heated air is driven; however hot this air may be made, it is impossible by its means to burn the syrup, the heat being instantly absorbed by the particles of water, as they are carried off by the blast. By an ingenious arrangement the liquor is continually passed into and removed from the interior of the cylinder. When it is remembered that its inner surface exposes to the drying action of the hot blast a surface of syrup of more than 192 square feet, it is no matter for wonder that the desiccation proceeds very rapidly. On the removal of the liquor after a stay in the cylinder of a very few minutes all possibility of fermentation is at an end, and the concentrated syrup might in this state be safely stored in bottles or casks for shipment. To do this would, however, be to carry with the sugar a small quantity of water, and to incur the risk of leakage. It is, therefore, passed to the third and last part of the machine, called the drum.

The drum is a large cylinder of iron and copper, 4 feet long and 4 feet diameter, heated within by waste steam from the small engine, and the syrup is distributed along its surface. The drum is driven slowly at the rate of two revolutions per minute, and its surface is swept over by a hot blast, which removes from the syrup the last particles of water, thus finishing the formation of the concrete. This is taken off as fast as it is formed, by a scraper attached for the purpose. While warm it is plastic, and may be cast into blocks of any convenient shape and size, but it hardens as it cools. In this state it may safely be packed for shipment in bags or matting; it shows no tendency to deliquesce, and of course cannot drain. (A sample of sugar and molasses prepared under the ordinary process, and a sample of concrete from the same juice prepared by Fryer's process, were exhibited.) No lime or other chemical is used, and, as will be observed, no molasses are made. Whatever crystallised sugar is in the cane-juice is also present in the concrete. The colour of the concrete is so good as to be certainly preferred by the refiner to good Muscovado sugar, and its make does away with hogsheads, puncheons, molasses, rum, and curing-houses, while the increase in value and the saving of drainage appears to equal more than £4 sterling per hogshead. The concretor, the cost of which is about £1000, does its work at the rate of 10 cwt. per hour.

A tificial refrigeration is evidently destined to receive most important industrial applications. Already, in the paraffin oil manufacture, and in the ingenious process by which M. Balard and M. Merle obtain chloride of potassium from sea-water, it renders most valuable service; and now M. Alvaro Reynoso, of Havanna, is applying it to the concentration of syrups. In face of the well-known fact that water, in freezing, becomes completely separated from whatever it may have previously held in solution, and of the successful working of the process by which Carré and others produce any desired degree of cold by mechanical means at a scarcely appreciable cost, one wonders that no one should have thought before of applying artificial cold to the extraction of sugar from syrups, especially when it is remembered how injurious the action of heat is apt to be. However, M. Reynoso has conceived the idea at last, and is devoting himself energetically to its realisation. He is in England just now, testing the respective merits of the various cold-producing appliances in use here. He has found that a syrup marking only 6° of Beaumé's saccharometer becomes converted by congelation into ice and a syrup of 30°. Should it be found that the cold does not injure the syrup, we may look to see great changes in the processes of sugar manufacture.

A few words upon Chinese sugar. It appears that much extra ground has been set apart at Swatow this year for the cultivation of sugar, in consequence of the demand in the north of China for this product. The Chinese method of pressing sugar is most rude. The cane is passed between two perpendicular granite cylinders—one, being turned by oxen, gives a motion to the others by means of cogs cut in the granite, and shod with hard wood; the juice is thus expelled, and runs through a channel cut for that purpose into a large wooden tub, from which it is removed to the boiling hut closely adjoining. These cylinders are not at all firmly fixed, depending altogether upon their weight to keep them in position. A company of Europeans working a modern sugar mill might make a large profit, if the Chinese would consent to sell their crops when ready for cutting. An improved cane mill was imported by an English firm, but the natives refused to purchase or even try it—a fact not to be wondered at when we find people taking a pride in defying all change.

In concluding this paper, the author would observe that he could wish it had been more comparative in its character than it is. But, as an excuse, he pleads the difficulty of obtaining information of practical improvements, by which alone the desired character of the paper could be attained. It is, however, to be hoped that the discussion may elicit facts which have not come within the author's reach. It was originally intended that the paper should embrace the refining processes; this was, however, found impossible, but the author hopes the object may be compassed at some future period.

ON SOME OF THE RECENT DISCOVERIES IN CHEMISTRY APPLICABLE TO THE ARTS.

By Dr. F. Crace Calvert.

In this lecture I intend to treat of chemistry applied to the arts, and more especially to some of the discoveries which have been made within the last two years. Many of these will appear to be incomplete; but if complete they would not be new, for seldom are discoveries perfected at once: they are generally the result of many years' study, and of the thoughtful consideration of several men.

The first part of this lecture will have reference to some of the applications which the laws of light have received during the last few years; and it will, I hope, convince of the necessity of every one engaged in the arts making himself acquainted with all the laws connected with the phenomena of light, to enable him to appreciate the discoveries which have been made, or to assist him in improving upon those which are already known, as they are constantly receiving the most valuable applications in the arts and manufactures. Thus, for example, M. Donné has applied the properties of light to ascertain the relative values of milks by the amount of cream they contain, and this he effects by an instrument which he calls the lactoscope. Dubosch Soleil has applied with great success one of the most complicated laws of light—viz., polarised light—to the commercial estimation of the various qualities of sugar. By this process the sugar refiner, or any other person interested in that product, is enabled to ascertain in half-an-hour exactly the amount of crystallised sugar there is in a given sample, as compared with the quantity of non-crystallisable, or what is commonly called treacle. M. Dubosch Soleil's apparatus is considered so accurate that the French Government has adopted it to determine the value of raw sugars imported into the country, and the customs duties are levied upon the results given by this instrument. I may further add that this apparatus, called "Polarising Saccharometer," is based on the peculiar property which light has when polarised, or when its rays are received at an angle of 35°25′ on a plate of tourmaline or a mirror. M. Dubosch Soleil's apparatus enables him to work with polarised light, which presents the various colours of the spectrum in such a way as to enable him thereby to determine, as I have already stated, the amount of crystallisable sugar in any given quantity of the article, sufficiently accurately for all commercial purposes.

It is impossible for me, in a single lecture, to attempt to give an idea of the various improvements which have been effected, even within the last two years, in the arts of photography, Talbotype, photozincography, glyphography, or other processes which are due to the action of light on sensitive surfaces. Still there are two discoveries which appear to me to deserve passing notice, viz., the carbon process of Mr. Swan, and also the process discovered by M. Villème, and now carried on in London by a company, by which the operator is enabled not only to take the photograph of a person, but to produce a statuette giving a full representation of the figure itself, and a far more accurate personification than could be produced by any sculptor, and that at a cost of as many shillings as the sculptor would expect pounds. But the most important series of researches which have been made of late years in connection with photography, and to which I deem it my duty to call especial attention, are such as to acquire more and more importance as they are more developed; I therefore feel convinced that anyone who will devote his talents to the study of this particular branch of photography will in time be amply rewarded, and of this there can be no doubt, when we consider the results already obtained by the labours of only two or three gentlemen. I refer to the reproduction of the various colours of the spectrum upon sensitive surfaces. In 1838, Herschel was the first to publish a paper on the various colours which chloride of silver is susceptible of taking under the influence of certain coloured rays of light. Mr. Robert Hunt also published, in 1840, a paper referring to the subject; but the most complete series of researches on the subject of the reproduction of the colours of the spectrum, and which led to a process by which several of the colours of the spectrum could be reproduced on a sensitive surface, is due to Edmund Becquerel. The results arrived at by this gentleman were so remarkable, that they drew the attention of the whole scientific world; and the following is an outline of the processes which were applied by him to obtain this interesting result. He took a daguerreotype plate, or a silver plated one, and having dipped it in a weak solution of chlorine, or, what was still better, a weak solution of hydrochloric acid, by connecting it with the poles of a battery the brilliant silver surface acquired different tints, passing gradually from an opaque white to a black tint. He also observed that the tint best suited to obtain favourable results was when the plate had acquired a pearlish pink; and although he found that the plate so prepared, when placed in the camera obscura, assumed the colours composing the spectrum, still they were faint, but he remedied this defect of intensity of tints by heating for several hours to a temperature of 95° to 100° the chlorinated plate, and then submitting it to the influence of the various colours composing the spectrum. Further, in the course of his studies he made the important observation that he could replace the peculiar action of heat on his prepared daguerreotype plate by exposing it to the rays of the sun under a sheet of paper which had been steeped in an acid solution of sulphate of quinine. The effect of this was that the plate of silver assumed an intense white colour, nearly resembling that of paper; whilst, if the protective paper had not been used, the silver plate would have gradually acquired a dark tint, and would have lost the whole of its sensitive properties, the protective paper having the power of arresting completely the most refrangible rays of light, especially those which are beyond the line H of the spectrum. Notwithstanding M. Edmund Becquerel's ardent hopes to find a method which would enable him to fix on a sensitive surface the various colours of the spectrum, still he failed, for they faded immediately they were exposed to the direct rays of light, and could only be preserved in obscurity. But there is one gentleman who deserves great praise for the extraordinary perseverance which he has shown in this class of investigation. I mean the nephew of the discoverer of photography, M. Nièpce de Saint Victor. Although I will

* From the Journal of the Society of Arts.

not enter here into the details of these valuable researches, as they can be found in the *Comptes Rendus de l'Académie des Sciences*, still I may just be allowed to state that he has not only by the following process obtained far more brilliant colours than those first produced by M. Becquerel, but has succeeded in reproducing on sensitive plates the various colours of coloured surfaces, such as are presented by fabrics, flowers, &c., and further, he has lately been so fortunate as to reproduce on his plates yellow and black tints, which had resisted all previous attempts. To give you an idea of the facts arrived at by this gentleman, I may state that he has succeeded in so fixing upon sensitive surfaces, the various colours of the spectrum, or of coloured surfaces, that they will bear the action of diffused light for several days. In fact, I have seen photographs which reproduced faithfully a small doll dressed up in various colours, and in which even the most minute ornament could be traced, and, what is certainly not less interesting was the reproduction of the irridescent colours of the peacock's feather. To obtain these marvellous results, M. Nièpce de Saint Victor takes a daguerreotype, or silver-coated plate, and dips it into a weak solution of hypochlorite of sodium, having a specific gravity of 1·35, until it has assumed a bright pinkish hue. The plate is then covered with a solution of dextrine, saturated with chloride of lead; it is then dried, and subsequently submitted to the action of heat, as in M. Becquerel's experiment, or under the screen of sulphate of quinine, also referred to above. The plate is then ready to be placed in the camera obscura, and to receive the colours of the spectrum, or representations of nature, such as flowers, as well as certain colours produced by man. Lastly, he succeeds in increasing the stability of the colours developed on the sensitive surface, by covering the plate with an alcoholic solution of gum benzoin; and M. Nièpce gives the name of Helio-chromie to this branch of photography.

During his lengthened researches, M. Nièpce de St. Victor has made two series of observations which I deem it my duty to lay before you, viz., that he can produce with facility, on prepared plates, the binary colours of the spectrum, viz., orange, violet, indigo, and green, if those colours are natural; but if they are artificially produced by the mixing of two of the primary colours, as red and yellow, or orange and blue, and yellow or blue, he cannot reproduce the binary colour, but only one of the two colours employed by the artisan to prepare them. Thus, for example, he can reproduce the natural green of malachite, and the beautiful colour known as Schiele's green, but he cannot do so with a mixture of Prussian-blue and yellow chromate of lead, the blue only re-appearing. These facts enable him to explain why, in ordinary photography, the leaves of plants always appear black, and why, when he attempts to fix on his plates the colours of leaves they have a blueish hue, the yellow portion of the colour not being reproducible.

M. Nièpce has made another series of observations which deserve notice, viz., that when a plate, as prepared by his process, is dipped in an alcoholic solution of substances susceptible of imparting a colour to flame, such, for example, as strontia, which communicates a red hue to it, or baryta, which gives a yellowish-green colour, the prepared plates when exposed in the camera will assume the same colour as the salt which they have on their surface would impart to the flame of alcohol; and if a salt of copper be used, which has the property of communicating a variety of tints to the flame of alcohol, the plate also will assume a variety of tints when exposed to the action of light; and during a certain period of his lengthy researches, M. Nièpce availed himself of this curious phenomenon to obtain coloured plates in the camera. They are not only interesting as reproductions of art, and as a feat of extraordinary skill in the progress of photography, but they are especially so because in time they will lead to methods which will enable us to communicate to our little children perfect and correct views of our time, and other interesting facts connected with the period in which we live.

All persons interested in the progress of photography, will find full details of the new processes for reproducing vitrified photographic plates in vol. 60, page 1239, of the *Comptes Rendus de l'Académie des Sciences*, 1865; these I omit, as they are purely technical, and have only an interest for those immediately engaged in that branch of the photographic art.

I shall now call attention to a most important series of researches published by Professors Bunsen and Roscoe; but, to enable you to appreciate their value, it is necessary that I should make the following remarks:—It is now well known that the solar spectrum is composed of three primary colours—blue, yellow, and red; and also of four complementary or binary colours, viz.—orange, green, indigo, and violet. It is also known that those colours represent different properties or qualities of that universal fluid called Ether, which, I may say, was generalised by Sir Isaac Newton under the name of Gravitation, on which the whole of the planetary system is based, and which gives to the universe its harmony and stability. This fluid is susceptible, under certain influences, as those generated by the sun, of being set in vibration, and thus are generated heat, light, and chemical rays; and further, as there is no chemical action without a corresponding production of electricity, it follows that electricity, as well as magnetism, may be considered as a mere modification in the vibrations of the same fluid. Therefore we may truly say that all the imponderable fluids called Light, Electricity, Heat, Magnetism, and Force, having all the same origin, namely, the fluid called ether, and which, according to the nature of the vibrations, developes or renders palpable to our senses one of those fluids. In fact, I feel convinced that this unique fluid is not converted into those divers fluids by special modifications of its own vibrations, but that they only become manifest to our senses when it has imparted its own or special vibration to the particles of matter, and that it is the peculiar vibration which it imparts to the molecules of matter that developes in the molecules themselves such a mode of vibration as gives birth to what we call light, electricity, magnetism, heat, and force. In fact, there is no doubt, from the researches of Dr. J. P. Joule, Profs. William Thomson, Mayers, and others, that heat and force are the same fluid, for Dr. Joule has given us the exact measurement of that force. He has demonstrated that the amount of heat necessary to raise one pound of water one degree in temperature, would, if applied mechanically, be competent to raise one pound weight 772 feet high, or it would raise 772 lb. one foot high. The term "foot-pound," has been introduced to express in a convenient or systematic way the lifting of 772 lb. to the height of one foot. Thus the quantity of heat necessary to raise the temperature of a pound of water one degree being taken as a standard, 772 foot pounds statute, is what is called the mechanical equivalent of heat. Dr. Tyndall in his valuable work on 'Heat considered as a Mode of Motion,' gives many interesting examples of the conversion of heat into force, and vice versâ. For example, he cites the following theory of Prof. Thomson, who assumes that an immense amount of force is converted into heat when meteoric matter is attracted to the surface of the sun by the molecular attraction called gravitation; that the force generated by the immense velocity with which meteoric matters travel towards the sun, becomes converted instantly by its contact with the sun into heat; and further, he considers, that the showering of meteoric matter, as well as that of the zodiacal lights on the sun's surface, are sufficient to account for the immense heat which he supposes the sun's surface to possess. I must say that I do not believe that the sun possesses much heat or light; I believe that it is only an immense mass which, by its size as compared with the rest of the planetary system, becomes the centre of gravitation; and that there exists between it and the planetary bodies a constant state of attraction; that the fluid called ether, which represents the force called gravitation, is in a constant state of activity throughout the universe, and brings about that Godly and admirable harmony which pervades it; and although the ether filling space can be considered in a constant state of action or vibration, and convertible into the fluids which we call heat, light, electricity, and magnetism, still these fluids only become manifest to our senses when they put into vibration the particles of matter, or produce, according to their peculiar vibration, the phenomena of light, electricity, magnetism, heat, and force; for if heat is convertible into force, as asserted by the researches of the eminent *savants* above stated, why should not the production of other fluids be due also to similar pheuomena? If it be true, as Joule, Thomson, and others contend, that force and heat are due to the vibration of the molecules of matter, and that according to the rapidity of the vibrations of such atoms (imparted to them by the vibrations of ether) one or other of these forces is engendered, why should not the manifestations of other fluids be traced to similar causes? In fact, no doubt can exist in my opinion with respect to electricity and magnetism, for if their manifestations to our senses were owing to the vibration of a universal force it would affect all bodies in the same way and in the same degree. Now this is not the case; for there are good and bad conductors. Therefore it follows that the atoms composing matter, or more so, their nature, have an influence on its degree of manifestation. The same with magnetism; for we find oxygen to be magnetic, and nitrogen non-magnetic or diamagnetic. Thus it appears to me from these facts, which might be multiplied if time permitted, that the manifestations of heat, force, electricity, and magnetism, are not peculiar and distinctive fluids, but are due to the modification in the mode of vibration of the universal fluid called ether, which imparts to matter its peculiar undulations, and that these forces are only made manifest to us when the vibrations come into contact with solid matters, such as compose the atmosphere or the earth. Therefore, I am of opinion that there is no light, heat, electricity, or magnetism, beyond the limits of the atmosphere which surround the earth; but that when the ether, which is in a state of vibration, comes in contact with the particles of matter composing our atmosphere, it then communicates one of its own peculiar vibrations to these particles; then, they by their vibrations, become luminous. If this theory is correct, it follows that the production of the phenomena of light is due to the vibrations of solid matter, and not to the vibrations of the ether, as is assumed by the philosophers of the day.

I very well know that these views of mine are completely in contradiction with those entertained by most of the philosophers of the day; but still I hope to be able to publish a sufficient number of scientific researches, as well as to draw attention to such a number of physical, chemical, and astronomical facts, as may, even if not proving the truth of my views, at all events, I hope, deserve some attention.

Now let us return to the subject under consideration, viz., that a spectrum is produced by the decomposition of light when it is refracted at an angle of 60°; and that the result of that decomposition is the production of three primary and four binary or complementary colours. Further, that the red portion of the spectrum represents calorific rays of light; that the green and yellow represent light-giving rays, and violet and the rays beyond it the chemical or actinic rays of the same. Philosophers have for a long period been able to measure accurately the intensity of the heat-giving rays, by means of a thermometer or the thermo-electric pile; and though we had a general knowledge of the intensity of the chemical rays of light, still we had no method of accurately measuring its real intensity, and conveying our results and observations to others, till Professors Bunsen and Roscoe filled up this important gap. These gentlemen's researches will be of great service to science and to society, as they will throw much light on many meteorological data, and enable a chemist to study with more precision than has been previously done the chemical phenomena of vegetation, and other phenomena connected with the chemistry of agriculture. For example, the thermometric observations giving the mean monthly or yearly temperature of a country, by no means yield all the data required for the estimation of the true climatology of the place, or of its plant or animal producing capabilities. For these purposes we require to have not only the amount of solar heat directly or indirectly reaching the spot, but likewise the amount of chemical active solar light which may be present there. This is strikingly exemplified by the following example given by Dr. Roscoe on a comparison of the mean annual temperature between Thorshawn, north latitude, 62° 2′; west longitude, 6° 46″; temperature, 45° 6′; and Carlisle, north latitude, 54° 55′; west longitude, 2° 58″; temperature, 46·9°; difference, 1·3. From these figures it will be seen that the mean annual temperature is nearly equal, but the quantity of sunlight falling upon those two places differs most widely, and we have a corresponding difference in true climatological results. Thus the flora of the Faroe Islands and the Shetland Islands is of a most limited description. Only hardy varieties of shrubs, and no trees or flowers exist there, while at Carlisle we have a luxuriant vegetation accompanying a most sunny sky. How essential, then, are the rays of light to vegetation. These gentlemen have also ascertained that those rays are in ratio with the intensity of that light; and still further, they are also in ratio with the chemical or actinic rays of the sun; and thus the researches of these savants will enable them to measure with accuracy those chemical actions. It is impossible, in a lecture like this, to render justice to their researches, therefore I must refer those who wish to consult them to the Philosophical Transactions of the Royal Society. Still I may state that these gentlemen's photochemical instruments are based on the following data, viz., that equal intensity of light produces in the same given space of time equal shades of tint on surfaces prepared with chloride of silver of uniform sensitiveness. Thus it is shown by experiments that a tint attained by paper so prepared is constant when the quantity of light falling upon it also remains constant. Light of an intensity of 50° falling upon a paper for the time of one minute produces the same blackening effect as light of the intensity of 1° falling upon it for the time of fifty minutes. Knowing these laws which regulate the degree of shade of the paper, and having a surface of a perfectly constant degree of sensitiveness, it is easy to obtain the absolute measurement of the chemical action of light.

The next discovery to which I desire to draw your attention is still in its infancy; but I am induced to refer to it from two considerations. The first, that it may render great service to society by enabling us to preserve the lives of many thousands of our fellow-creatures in coal-mines and other underground works, and also because it is a beautiful illustration of the amount of knowledge that a man requires at the present day either to understand or appreciate fully the discoveries of others, or to enable him to attempt any original invention of his own. Unless a person possesses the rudiments of the leading sciences of the day he will never be anything but an imitator, and will never succeed in improving the inventions already made. It is certainly most interesting to witness how the most abstruse branches of science are brought to bear on arts and manufactures, and no better example can be given than the application of electricity under various forms to what is commonly called the telegraph. The invention which I am now about to bring to your notice is due to M. Dumas, a young French engineer, and to M. Brequet, of Paris, who is also practically connected with telegraphy. To enable these gentlemen to carry out their discovery, they have had to study, and be perfectly acquainted with, the researches of many of the most eminent men that science has produced during the last half century. Thus they employ the galvanic battery, which was discovered by Galvani, and perfected by many philosophers, until brought at last to its present perfection. They use a mixture of bichromate of potash and sulphuric acid in a Bunsen battery. They have also had recourse to magneto-electricity, first discovered by Faraday, and brought to its present perfection by the researches of MM. Nobili, Mason, Becquérel, Joule, and others; and to enable them to construct their apparatus they have applied, with great ingenuity, the inductive coil, the result of many successive discoveries, and brought to great perfection by Ruhmkorff; the vibrating interrupter of Dancer, and also the condenser of Fiquier. Further, they must have had the knowledge of the stratified light and the application of it by Gassiot: the fluoresence of light by Stokes and Becquerel, and their applications to glass by Geissler. All these facts prove the correctness of my statement, how vast is the amount of knowledge required to make a little discovery. The apparatus invented by these gentlemen is portable, for a miner carries on his back the above-mentioned galvanic battery, and this generates the force required, which is multiplied, increased, and brought to light by the Ruhmkorff coil, which is also confined in the same leather case, occupying only six inches; the magneto-electricity passes through wires covered by vulcanised india-rubber, and these are in connection with a thick glass tube, in which a vacuum has been made, and this contains a fluorescent tube of Geissler, which becomes luminous or fluorescent by the passage of the electricity through it, generated by the coil and the battery.

Although both light and electricity are most interesting subjects, and could well be made the subject of many lectures, still I am bound to leave them on one side, and draw your attention to other facts deserving of notice. It is well known to all chemists and philosophers that matter has a great tendency to assume a geometrical or crystalline form, and that whenever the atoms of matter are sufficiently free for molecular attraction to have its full influences, attraction between the atoms takes place, and gives birth to well-defined crystals. The following examples can be cited:—The slow condensation of the vapour of iodine, which gives rise to well-defined crystals, as well as those of camphor and other volatile bodies. When sulphur, bismuth, and other substances are melted, and allowed to cool slowly, and the excess of the fluid remaining among the crystals is poured off, well-defined crystals are found to exist in the mass, which apparently would have disappeared had not the excess of fluids been poured off, for in this case the molecules of the remaining fluid mass would have solidified among the crystals, and would have prevented the observer from seeing that the molecules when freed in the fused mass had assumed a crystalline form. The tendency of molecules to assume a geometrical form presents in many instances curious phenomena. Thus, for example, a vessel may contain acetic and carbolic acids—and if, say at a temperature of 40° or 50°, a crystal of either of those substances is placed in contact with its own fluid, the entire bulk of fluid passes in a few seconds into a solid crystalline mass. The manifestation of that force is also beautifully illustrated in the following instance:—If a tin plate be heated to a moderate temperature, and a drop of water be allowed to fall on its surface, and the plate be dipped for a few minutes into weak muriatic acid, it will be observed that the whole surface of the plate is affected, and that where the water fell it has assumed a most beautifully waved and irridescent surface. If this surface be examined under the microscope it will be found that under the influence of the vibrations generated by the cold fluid falling upon the heated plate, the mass of molecules have passed from their amorphous condition to that of a crystallised one. We all know this alteration in the tin-plate surface was particularly applied many years ago to produce variegated surfaces on our tea-trays and other similar domestic vessels. It should also be stated that this effect was greatly enhanced by the skilful application of coloured varnishes, which increased the value of the mercantile article. This discovery, which is due to an eminent chemist of the name of Prout, clearly proves, as those before cited, the power which matter has to assume a crystalline form. I cannot, however, refrain from adding the following instances, in which the mere vibration of particles of matter is sufficient to change amorphous bodies into crystalline ones. The first is that which often takes place in the iron used on railways. The most striking example is that of the iron links used to unite waggons, where it is found that the fibrous, tenacious link made of malleable iron is transformed into a crystallised brittle link by the constant vibration it is subjected to by railway traffic. Another example is that shown by the peculiar action exercised by intense cold on the molecular state of iron, as shown by the brittleness of the metal in Russia and other cold climates; this was the case in December 1859, in England, when, as will be remembered with regret, many railway accidents occured, owing to the rails becoming crystallised and brittle.

The power which molecules have to assume a crystalline form has recently been the study of Mr. F. Kulhmann, an eminent chemist of Lisle, and he has given to that force the name "crystallogenic." I shall endeavour to lay before you a short epitome of his researches, which are not only interesting in a scientific point of view, but also in consequence of the mode in which he has applied it in connection with arts and manufactures; and those who take an especial interest in the matter will read with pleasure his researches in the *Comptes Rendus de l'Académie des Sciences de Paris*. M. Kuhlmann, having mixed a certain class of substances which crystallised with facility, such as mannite, sulphate of zinc, iron, copper, with a thick solution of gum, or any other substances interfering with the free crystallisation of these substances, and having spread the mixtures on glass, he found, by exposing such prepared plates to the atmosphere, that gradually the water would evaporate, leaving a dry mass, in which could be observed most beautiful arborisations. Each of the solutions will produce a well-defined design which is not always identical although operating under the same circumstances. Still they assume very similar forms, being in some instances that of stars, and in others that of leaves and wreaths. These modifications are obtained by the strength of the solution, the nature of the salt, and the mode of preparation. Kuhlmann further observed, that if amorphous substances, such as magnesia and sesqui-oxide of iron, or chromium, be mixed with bodies susceptible of crystallisation, and these added to a gummy fluid, the amorphous particles are drawn into the crystallising substances, and follow the outlines; and if these are produced on surfaces, such as those of glass or porcelain, and heat applied, the gummy matter will be destroyed or volatilised, and the crystalline medium and the amorphous substances become incorporated, and fixed in the porcelain, reproducing on its surface a crystallogenic design. These researches which I have the pleasure to lay before you will show you the probability of carrying out these results to a satisfactory issue. Of course, the glass or porcelain manufacturer will easily understand that he will have to use borax or phosphate of soda, or other flux, as a crystallising medium, if he wants to produce in his art the results that I have stated. M. Kuhlmann has applied his crystallogenic process with great success to photography, and also to the art of engraving metals. As the latter may have some interest, I will give you an outline of his process. It consists in producing a crystallogenic design on the surface of an iron or copper plate, and then applying on the so-prepared surface, say a sheet of lead or copper, and submitting them to high pressure; when the design would be impressed upon the plate. The embossed plates, by being placed in a prepared solution, and in connection with a galvanic current, will easily give birth to a fac-simile in relief, which can be used as a printing surface. It is with pleasure that I am able to state that, though I part from these interesting researches for the present, I shall have the pleasure of referring to them again in a subsequent part of this course of lectures, when I shall speak of some researches of this gentleman which have a more immediate bearing on the progress of science.

It has been for a long time a disputed question whether the stained windows we all admire in old cathedrals, could be restored in such a way as to resume the brilliancy they had at the time they were placed there by the artists. At all events, there is now no doubt that this can be effected by the process discovered by my eminent master, M. E. Chevreul, as is proved by the application of it in connection with the restoration of stained windows existing in a well-known church in Paris—that from which the tocsin of St. Bartholomew was sounded, "St. Germain des Prés." The process devised by M. Chevreul is highly practical; it consists in removing the stained glass from the windows, and dipping it for several days, first, in a weak solution of carbonate of soda of a specific gravity of 1·068 then washing it, and dipping it for several hours in a solution of muriatic acid of a specific gravity of 1·080. On the glass being washed and dried it will be found as brilliant and beautiful as when it came from the hand of the manufacturer. M. Chevreul has found that the dim and dirty appearance which stained glass assumes by time is due, especially in large towns, to the various products of smoke being first condensed on the glass by fog and rain, and then becoming oxydised they act as a cement to various mineral matters, such as chalk, gypsum, oxyde of iron, &c., which help to impoverish the transparency of the glass. The alkali acts upon the organic matter and dissolves it, while the muriatic acid removes the minerals. The durability of glass placed in our monuments is extraordinary, when we bear in mind the curious results published some years since by the eminent chemist, Pelouze, who observed that when window, bottle, and other varieties of glass were reduced to a fine powder, and mixed with water, they were soon acted on, yielding a large quantity of silicate of soda to that fluid, amounting in several cases to eight or ten per cent. in cold water, and even to thirty-six per cent. when the finely pulverised glass was boiled in water; and that, in many cases, it was a definite compound which was dissolved from the glass, namely, a silicate of soda, composed of three equivalents of silica and two equivalents of soda. M. Pelouze explains the extraordinary difference in the effect which water produces on glass when in large masses or plates, as compared with its influence on the same substance when reduced into a fine state of powder, by assuming that, in the first instance, water does not act because it seldom remains sufficiently long in contact with the glass to act upon the elements which compose it; while, in the second case, there exists numerous points of contact between the fluid and the solid body, thus facilitating the action of the fluid on the solid material. I am inclined to think that the peculiar molecular condition the surface of glass assumes, when manufactured in plates or otherwise, must exercise a great influence on the property which glass has to resist the action of water. If it were not so, how could be explained the limited action which watery fluids, such as wine, cause upon the interior surface of a bottle, though they remain in contact for many years? I can conceive glass assuming a peculiar surface by the pressure of the atmosphere, thereby producing a homogeneous one susceptible of resisting the action of water. A similar instance occurs in the case of polished steel, or of the rolled surface of wrought-iron, or the skin of cast-iron, which resist the chemical action of either air or acids in a far greater degree than does the interior of the substances which compose those metallic bodies.

Whilst dwelling upon old materials, I will give an outline of a process devised by M. Stahl for the preservation of antediluvian fossils. We are aware how interesting it is to preserve relics of past ages, giving us some of the conditions of the world at various periods. Those relics are exceedingly fragile, and after many clumsy attempts M. Stahl arrived at his discovery. If the fossil

BLAST FURNACES.

Fig. 1.

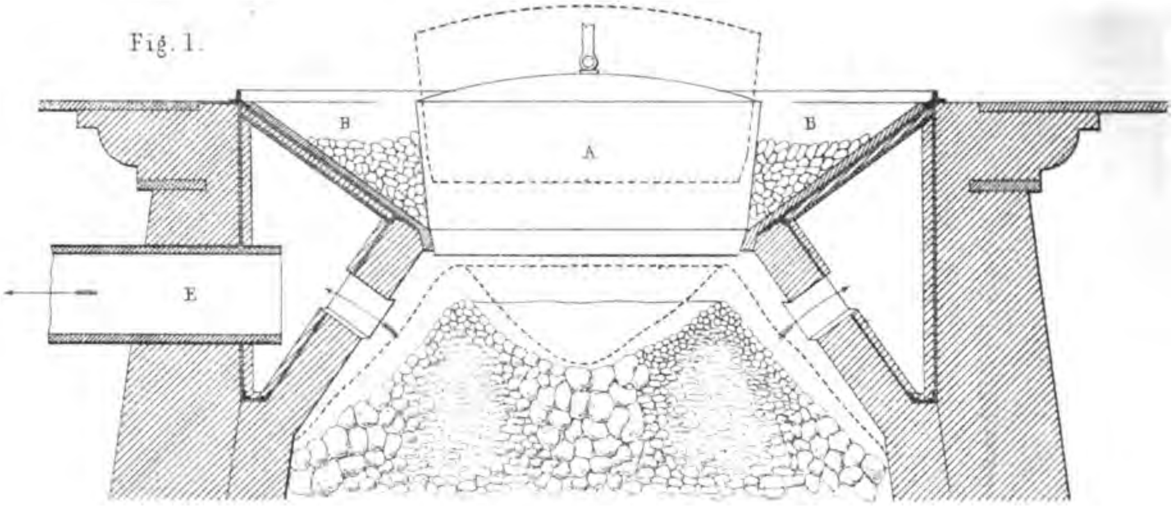


Fig. 2.

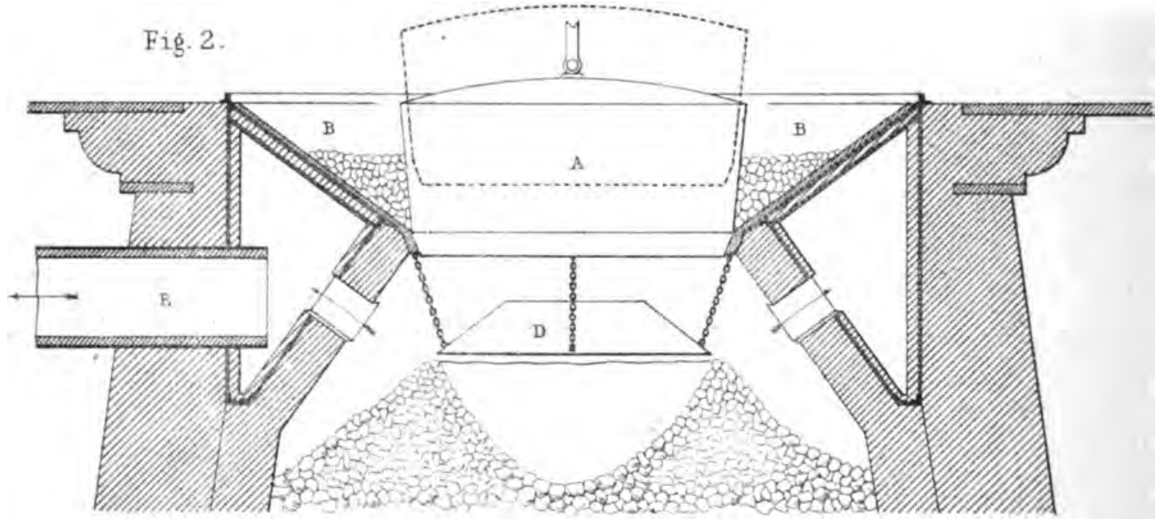
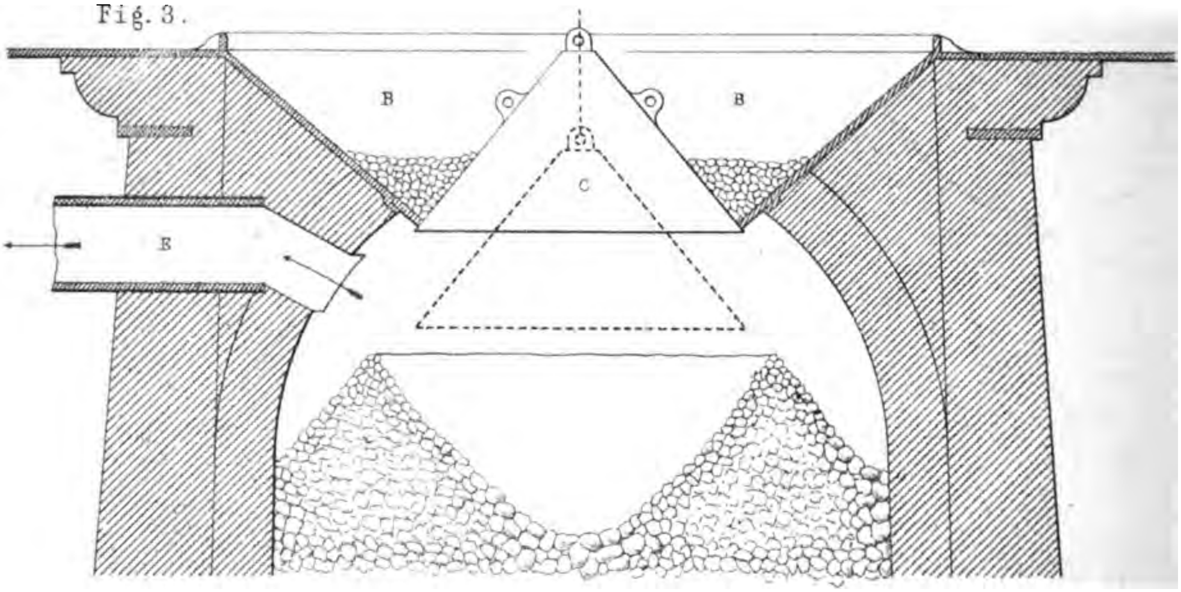


Fig. 3.



SCALE.

0 5 10 15 FEET.

is compact and comparatively firm, it is saturated by means of a brush with melted spermaceti, but if it is friable it is necessary to employ a melted mass composed of four parts of spermaceti and one of colophany resin, which in cooling gives great solidity to the mass of the fossil.

I would, in conclusion, draw the special attention to all artists who take an interest in decorative art to the interesting papers published recently by M. Oufroy on the one hand, and M. Wiel, of Paris, on the other; the first being in the *Technologiste* of last year, the latter in the *Annales de Chimie et de Physique*, on their respective methods for covering a metal with another, more valuable by its properties or precious by its qualities. These methods have a special reference to cast-iron or wrought-iron. In Paris these processes, which may be regarded as not only ornamental but useful, have been applied with great success. Thus, for example, instead of the dirty, pitchy black lamposts which ornament our English towns, there can be seen in Paris elegant, well-designed, bronze-like posts, which are pleasing to the eye. The same can be said of the fountains on the Boulevard Sebastopol, the Palace de la Concorde, and many other public promenades in Paris, which excite the admiration of foreigners visiting that city.

ON THE WORKING AND CAPACITY OF BLAST FURNACES.*

By Charles Cochrane.

(*With an Engraving.*)

My method of taking off the gas from a close-topped furnace at the Ormesby Works, Middlesbrough, and the construction of such closed top and lifting valve for charging, will be thoroughly understood by reference to Plate 39, and the figures represented thereon; Fig. 1, being a sectional view of the original construction of closed top, with lifting valve, used at the above works; and Fig. 2, shows a similar experimentally used of the internal distributing cone, with lifting valve; and Fig. 3, another section of closed top, with lowering cone valve—this arrangement being the one finally adopted and in general use: Fig. 1, exhibits the materials being filled into the exterior space B, surrounding the charging valve A, which is drawn up into the position shown by the dotted lines for allowing the materials to fall into the furnace; while the gas is taken off from the furnace top by the passage E.

The usual plan of closed top adopted in blast furnaces is that represented in Fig. 3, Plate 39, in which it will be seen that the materials are filled in against a lowering cone C, placed in the throat of the furnace, which on being lowered into the position shown dotted permits their fall into the furnace. The tendency of the material in this case is to roll outwards from the charging cone to the side of the furnace, and thence back again to the centre, as shown in the drawing.

It was thought at the time of adopting the plan shown in Fig. 1, Plate 39, that the height of the materials carried by the same furnace would be increased, and that a corresponding economy in consumption of fuel would result, owing to the circumstance that where the plan shown in Fig. 3 is adopted, the level of the materials must always be maintained at a certain distance below the top, to ensure the fall of the cone C at charging time. The plan shown in Fig. 1 was devised with due regard, as it was thought, to the arrangement of the materials in the furnace; and it was intended that they should arrange themselves as shown by the dotted line in that drawing, part of the larger material rolling to the outside of the furnace and part to the centre.

As long as the furnace could be kept so full as to ensure the arrangement of materials shown by the dotted line in Fig. 1, there was no reason that it should not work uniformly; but the practical result was that it was found impossible to keep the furnace sufficiently full to secure the distribution of the materials in the manner intended. The level of the surface of the materials was generally below that intended, the consequence of which was that the material on falling into the furnace was shot into the centre, from whence the largest pieces rolled outwards, and the whole charge arranged itself as shown by the full line in Fig. 1. The result of this was irregular working of the furnace over a period of many months, during which an explanation of the irregularity was in vain sought for. At one time it was thought the back pressure of the escaping gas had something to do with the irregularity; at another the cause was sought for in the difficulty of keeping the hopper valve A of the furnace tight, and the necessity for using small material around the valve as a kind of lute between every charge, to prevent the escape of the gas: until it occurred to the writer that the arrangement of the materials in the furnace was the sole explanation of the difficulty, and that as all the material was shot into the centre of the furnace the small pieces would remain there whilst the large would roll to the outside. Believing that it was of great importance, in order to secure uniform results, that there should be a uniform distribution of the heated gas from the hearth over the entire horizontal area of the furnace at each stage of its height, he considered that the effect of any small material being collected in any portion of the area would be to obstruct the passage of the gas at that part, and so prevent that portion of the material from being heated to its proper degree of temperature.

Deeming this to be the explanation of the irregularities experienced in the working of the furnace, the writer devised a method of distributing the material so as to prevent such a result, by the introduction of a frustum of a cone D, Fig. 2, suspended inside the throat of the furnace, which was found to be all that was necessary. The materials then arranged themselves in the desired manner, as shown in the drawing; and the result has since been a perfect uniformity in the working of the furnace. Where previously a yield of foundry iron from the same furnace could not be relied upon for more than about 24 hours at a time, and the annoyance was incurred of the furnace suddenly changing to white iron, the production of white iron except when desired is now unknown. A consideration of these facts will lead to a fair estimate of the importance of the arrangement of the materials in a blast furnace. Anything that opposes the free passage of the ascending heated gas at any part of the furnace must direct the gas into another channel, and the material thus left insufficiently acted upon finds its way into the hearth at a low temperature, and white iron is the result.

The effect produced on the distribution of material by this internal frustum of a cone is obviously similar to that of the ordinary lowering cone when lowered, shown in Fig. 3, Plate 30; and the latter has now consequently been finally adopted at the Ormesby Iron Works as the permanent form of the arrangement, and is now being carried out there.

The most perfect action of a blast furnace consists in the development of the highest temperature needed for the production of the required quality of iron, in a layer or stratum as little removed from the tuyeres as possible; and the gradual absorption of the heat from the ascending gas by the materials through which it passes, until it leaves the throat of the furnace at the lowest possible temperature. Anything which tends to cause a more perfect absorption of the heat developed in the hearth, or to lower the level of the region of highest temperature in the furnace, will thus be beneficial.

With regard to the absorption of the heat from the gas, it is obvious that the hotter the temperature at which the gas escapes, the more wasteful must be the effect; and theoretically the height of a furnace should be increased until the temperature of the escaping gas is reduced to that of the materials on their introduction into the furnace top. This is the theoretical limit to the height of a blast furnace: but it must not be forgotten that the less the difference in temperature between two bodies, the less rapid is the communication of heat from the hotter to the cooler; hence for the absorption of the last few degrees of temperature from the ascending gas a much greater height of material is necessary than where the gas and the material differ more widely in temperature. Already with 50 to 60 feet height of blast furnace in the Middlesbrough district the temperature of the escaping gas does not exceed 500° to 600° Fahr.; and it is a question to be answered only by experiment how far the gain from the heights of 70 to 75 feet already accomplished at Middlesbrough, and further heights of 10 or 20 feet additional that are contemplated, will compensate for the extra work in raising the materials to the additional height and for the more substantial plant required. In the direction of height there is unquestionably on this account a limit which will speedily be attained; supposing the limit be not previously determined by the necessity for increased pressure of blast and by the increased difficulty in working the furnaces.

As regards the benefit produced in the working of a furnace by lowering the level of a region of highest temperature, it is evident that this benefit is of the same nature as in the previous

* Read at the Institution of Mechanical Engineers.

case, since the lowering of that level is equivalent to an increase in the height of the furnace. The level of the region of highest temperature is dependent upon the heat of the blast, and is brought down nearer to the tuyeres only by using the hotter blast: and in the writer's opinion the chief source of economy yet to be attained in the working of blast furnaces, independent of the more extended application of the waste gas, lies in the use of blast heated to a still higher temperature than that hitherto known. The yield of iron from any ironstone is governed by the percentage of iron it contains, and the consumption of limestone by the nature of the ironstone; and both these are therefore fixed quantities for the special materials employed. But that is not the case with the coke, which offers a fruitful source of saving; and in what way therefore this saving is effected by increased temperature of the blast, becomes a most important question, involving as it does the general theory of hot blast.

To explain the effect of the hot blast it is necessary to regard the nitrogen of the atmosphere and the generated carbonic oxide as the great heat "carriers" in the operations of the blast furnace. This consideration involves two others—namely, the time required for heating the nitrogen from its initial temperature at entering the furnace up to that needed for the fusion of the materials in the furnace; and also the method by which the gases are heated. Taking it for granted that the colder, and consequently the denser, pure oxygen is, the more intense is the combustion of any body burning in it, there is evidently no necessity for heating this constituent of the atmosphere. It is further obvious that supposing 3000° Fahr. be the temperature required for the fusion of the materials on their reaching the hearth, then every pound of the nitrogen introduced by the blast must be raised to that temperature before the fusion can take place.

Now in a cold-blast furnace the nitrogen is introduced at the lowest temperature, and requires necessarily the longest time for being raised to the requisite temperature; hence the maximum temperature in the furnace is produced at a higher level, and diffused over a larger portion of the furnace where it is not wanted; and it is consequently impossible in some cases ever to get the temperature sufficiently high at any part of the furnace to produce more than the qualities of iron known as forge iron. In proof of this may be mentioned an attempt made some years ago at the Ormesby Iron Works, Middlesbrough, to produce cold-blast iron of a grey or foundry quality. It was in vain however that the burden of ironstone was reduced, that is the proportion of coke increased: the temperature of the hearth could not be sufficiently raised to produce any other quality than forge iron, the effect of the reduced burden being only to throw an increased temperature into higher regions of the furnace. The attempt was consequently abandoned; not however until it became obvious that the burden might have been still further diminished with only the effect of diffusing the hottest temperature into still higher regions of the furnace.

Whatever heat is imparted to the nitrogen of the atmosphere, and also to the carbonic oxide generated in the furnace is, of course delivered up again to the materials in the furnace, excepting only the portion lost by the temperature at which the gas escapes at the throat of the furnace. The effect of heating the nitrogen before its entrance into the furnace now becomes more clear. It has a shorter distance to travel up within the furnace before the maximum temperature is attained, for the simple reason that, having been partly heated already it requires less time to become further heated to the temperature required in the furnace, having got the start by the amount of its initial temperature. Hence the fusing heat is generated nearer to the tuyeres; and this circumstance, together with the smaller expansion of hot blast compared with cold blast on entering the furnace, seems to furnish a satisfactory explanation of the more immediate effect of heated air in preventing diffusion within the furnace of the region of highest temperature.

As to the method of heating the nitrogen, it must be borne in mind that the heat generated in a blast furnace is obtained wholly or nearly so by the imperfect combustion of the carbon of the coke into carbonic oxide as the final result, a process by which theoretically only about one fourth the total quantity of heat is developed that would be obtained by the perfect combustion of the same carbon into carbonic acid, showing a loss in the fuel of about 75 per cent. of heat; since one pound of carbon burnt into carbonic oxide developes only 2880 units of heat, whilst one pound of carbon burnt into carbonic acid developes about 11,700 units of heat. For although the combustion of the carbon of the coke in the blast furnace is partially or wholly into carbonic acid, so long as the supply of oxygen is in excess, this condition applies only to the lower portion of the furnace nearest the tuyeres; and this carbonic acid becomes ultimately reduced to carbonic oxide by passing through the excess of carbon in the mass of incandescent coke occupying the upper portion of the furnace. If therefore the nitrogen be heated partially or wholly before entering the furnace, by any means involving the perfect combustion of the fuel employed into carbonic acid, it follows that a large saving in fuel must necessarily result; and to give an idea of the real influence of the nitrogen of the atmosphere on the consumption of fuel in the blast furnace, the writer has endeavoured to express numerically the effects produced by taking three different cases of the blast entering the furnace at the various temperatures of 50°, 650°, and 1150°, Fahr. respectively. It is assumed that the air has to be heated within the furnace to 3000° Fahr. in each case; that one pound of carbon burnt into carbonic oxide will develope 2880 units of heat, that is, will raise 2880 lb. of water through 1° Fahr.; and that the specific heat of air is ·275, compared with that of water as 1·000. It is further assumed that 4500 cubic feet of blast enter the furnace per minute; and as 1000 cubic feet weigh 76 lb., the weight of blast entering the furnace per minute will be 342 lb., 77 per cent. of which or 263 lb. weight is nitrogen.

In the three cases cited it will be seen that the work to be done within the furnace is to raise the temperature of the air through

2950° in the first case.
2350° in the second.
1850° in the third.

In the first case, namely to heat 263 lb. of nitrogen through 2950°, there will be required

$$\frac{263 \times 2950 \times \cdot 275}{2880} = 74 \text{ lb. of carbon per minute.}$$

In the second case, namely to heat 263 lb. of nitrogen through 2350°, there will be required

$$\frac{263 \times 2350 \times \cdot 275}{2880} = 59 \text{ lb. of carbon per minute.}$$

In the third case, namely to heat 263 lb. of nitrogen through 1850°, there will be required

$$\frac{263 \times 1850 \times \cdot 275}{2880} = 46 \text{ lb. of carbon per minute.}$$

These results show that to raise the temperature of the blast from 50° to 650° before it enters the furnace causes a saving in the blast furnace of 15 lb. of coke out of 74, or about 20 per cent.; and that a further increase of temperature from 650° to 1150° occasions a saving of 13 lb. out of 59, or about 22 per cent. To show that these calculations are not so merely theoretical as might at first be supposed, it may be here stated that in the writer's experience the raising of the temperature of the blast from 650° to 1150° at the Ormesby Iron Works has accomplished an actual saving of from 17 to 18 per cent. of coke in the blast furnace; and this was effected at an expense of coal outside the furnace of about one half the weight of coke saved within the furnace. The writer believes however that, were it in his power to compare two exactly similar systems of hot-air stoves, the additional fuel consumed outside the furnace would approximate more nearly to one third of the weight saved inside the furnace than to one half. But the difficulty of having to compare the ordinary cast-iron stoves with the regenerative hot-blast stoves, by which the highest-named temperature of 1150° is attained, is too great to allow of the comparison being made more precisely.

In the cold-blast furnace the method of heating the air is simply by its direct contact with the heated material and incandescent coke, and it is heated altogether at the expense of carbon burnt only into carbonic oxide, instead of into carbonic acid. In the hot-blast furnace, by the more complete combustion of the heating fuel in the hot-blast stoves, exterior to the furnace, the nitrogen is heated not only at a cost of fuel represented by a saving of theoretically three-fourths in the actual weight of coke required within the furnace to raise the nitrogen, to the same temperature, but also with the further advantage that instead of burning coke it is coal that is used for the purpose. In other words, for every pound of coal economically burnt outside the furnace in raising the temperature of the blast, three pounds of coke will be saved within the furnace, whether the furnace be open or closed at the top.

It may be thought that a comparison made between an open-topped furnace where the gas burns freely as it escapes, and a close-topped furnace where no such combustion takes place, is not a fair one; and that the combustion of the gas at the throat of the open-topped furnace, by imparting heat to the materials at the throat of the furnace, would tell in favour of the consumption of fuel in the open-topped furnace. But facts speak otherwise, and it appears that there is practically no difference whatever due to this cause.

It will thus be seen that a definite limit to the height of a furnace is soon reached in practice; and that the advantage derived from increasing the actual height of a furnace may be partly secured by increasing the temperature of the blast, and thereby lowering the region of maximum temperature in the furnace.

The only question that remains is as to the diameter of the furnace. In reference to this dimension, the danger that has been alluded to from the formation of cold masses in the centre of a blast furnace serves as a caution against the more dangerous formation of cold masses attached to the sides of the furnace, technically called scaffoldings. It is obvious that, if the width of the boshes of a furnace be large in proportion to the height and the volume of the ascending gas, there will be a tendency to unequal diffusion of the heat imparted by that gas over the successive horizontal sections of the furnace, and irregularities in its working will consequently set in. There is then a limit to the diameter of the boshes, the largest of which yet in use is believed to be about 21 feet; beyond this size it appears very questionable whether any beneficial result would arise, though a furnace has been stated to be in course of construction at Cwm Celyn having a diameter of 24 feet at the boshes.

The nature of the materials of the charge in any contemplated increase of the dimensions of a blast furnace must be most scrupulously borne in mind. The density of the coke is the most important consideration; but next to that is the friability of the ironstone itself. In the Staffordshire district it would be useless to build furnaces of the height contemplated and actually employed in the Middlesbrough district, for the simple reason that the Staffordshire coke is friable, and would be crushed most injuriously by the weight of superimposed material.

It is thus evident that the actual dimensions of a blast furnace in any particular instance are much dependent upon special local circumstances; but the writer has endeavoured to point out the general principles which guide the determination of the dimensions to be adopted.

Reviews.

Lives of Boulton and Watt, principally from the original Soho MSS.; comprising also a History of the Steam Engine. By Samuel Smiles. London: John Murray.

We have received, almost at the last moment of going to press, Mr. Smiles's last volume of the "Lives of Engineers," which comprises those of two of the most celebrated. So much has been written about Watt and the history of the steam engine, and his life by Mr. Muirhead seemed so completely to exhaust the subject, that it might be supposed nothing further could be said about it; but Mr. Smiles, nevertheless, seems to have collected a large quantity of additional interesting matter from the extensive collection of documents brought from Soho, now in possession of Mr. M. P. W. Boulton, of Jew Park, Oxon, the grandson we believe of the Boulton who was associated with Watt. The MS. papers consulted by the author consist, we are told, "of several thousand documents selected from the tons of business books and correspondence which had accumulated at Soho," which Mr. Smiles has turned to good account, and has produced a goodly volume, which, notwithstanding the ground has been gone over so often before, contains much original matter relating to persons whose careers in life must always be of great interest to all who delight to watch the progress and development of genius and great mechanical skill. In addition to the memoirs of Boulton and Watt, the volume contains memoirs of the other inventors who laboured at the invention and perfection of the steam engine, and the author has been enabled to gather from the Boulton papers a memoir of William Murdock, to whose inventive genius and great mechanical ingenuity sufficient tribute has not been paid by the public, who have profitted so much from his labours, one of which was the invention of gas lighting. This book, which contains upwards of 500 pages, is handsomely printed on toned paper; it is illustrated with two admirable portraits of Watt and of Boulton, and is abundantly embellished with wood engravings, many of them representing places associated with incidents in the life of Watt. We cannot at the present time examine further into the merits of the work, but must content ourselves with a few extracts. The first one describes the successful result of the first steam engine made at Soho.

"The first engine made at Soho was one ordered by John Wilkinson to blow the bellows of his ironworks at Broseley. Great interest was, of course, felt in the success of this engine. Watt took great pains with the drawings; the workmen did their best to execute the several parts accurately, for it was understood that many orders depended upon whether it worked satisfactorily or not. Wilkinson's iron-manufacturing neighbours, who were contemplating the erection of Newcomen engines, suspended their operations until they had an opportunity of seeing what Boulton and Watt's engine could do; and all looked forward to its completion with the most eager interest. When all was ready at Soho, the materials were packed up and sent to Broseley, Watt accompanying them to superintend the erection. He had as yet no assistant to whom he could intrust such a piece of work, on which so much depended. The engine was erected and ready for use about the beginning of 1776. As it approached completion Watt became increasingly anxious to make a trial of its powers. But Boulton wrote to him not to hurry—not to let the engine make a stroke until every possible hindrance to its successful action had been removed; "and then," said he, "in the name of God, fall to and do your best." The result of the extreme care taken with the construction and erection of the engine was entirely satisfactory. It worked to the admiration of all who saw it, and the fame of Boulton and Watt became great in the midland counties."

The manner in which Watt was surreptitiously deprived of pecuniary advantage from the invention of the crank engine is thus noticed:

"The Soho workmen were naturally curious about the new inventions and adaptations which Watt was constantly producing, and these usually formed the subject of conversation at their by-hours. While the model of the crank engine was under construction at Soho in the summer of 1780, a number of the workmen met one Saturday evening, according to custom, to drink together at the "Waggon and Horses," a little old-fashioned, low-roofed, roadside public-house, still standing in the village of Handsworth. The men were seated round the little kitchen-parlour, talking about their work, and boasting, as men will do over their beer, of the new and wonderful things which they were carrying forward in the shops. Dick Cartwright, the pattern maker, was one of the loudest of the party. He was occupied upon a model for the purpose of producing rotary motion, which he declared would prove one of the best things Mr. Watt had ever brought out. The other men were curious to know all about it, and to illustrate the action of the machine, Cartwright proceeded to make a rude sketch of the crank upon the wooden table with a bit of chalk. A person who sat in the kitchen corner in the assumed garb of a workman, drank in greedily all that the men had been saying; for there were many eavesdroppers constantly hanging about Soho, some for the purpose of picking up surreptitious information, and others to decoy away skilled workmen who were in the secrets of the manufacture. Watt himself had never thought of taking out a patent for the crank, not believing it to be patentable; but the stranger aforesaid had no such hesitation, and it is said he posted straight to London, and anticipated Watt by securing a protection for the contrivance."

From the extremely interesting memoir of Murdock, we extract the following account of the commencement of his engagement with Boulton and Watt, and of his zeal in their service:

"William Murdock was not only a most excellent and steady workman, but a man of eminent mechanical genius. He was the first maker of a model locomotive in this country; he was the introducer of lighting by gas, and the inventor of many valuable parts of the working steam-engine hereafter to be described. His father was a millwright and miller, at Bellow Mill, near Old Cumnock, in Ayrshire, and was much esteemed for his probity and industry, as well as for his mechanical skill. He was the inventor of bevelled cast-iron gear for mills, and his son was proud to exhibit, on the lawn in front of his house at Sycamore Hill, Handsworth, a piece of the first work of the kind executed in Britain. It was cast for him at Carron Ironworks, after the pattern furnished by him, in 1766. William was born in 1754, and brought up to his father's trade. On arriving at manhood he became desirous of obtaining a larger experience of mill-work and mechanics than he could acquire in his father's little mill. Hearing of the fame of Boulton and Watt, and the success of their new engine, he determined to travel south, and seek for a job at Soho. Many Scotchmen were accustomed to call there on the same errand, probably relying on the known clanship of their countrymen, and thinking that they would find a friend and advocate in Watt. But strange to say, Watt did not think Scotchmen capable of becoming first-class mechanics.

When Murdock called at Soho, in the year 1777, to ask for a job, Watt was from home, but he saw Boulton, who was usually accessible to callers of every rank. In answer to Murdock's inquiry whether he could have a job, Boulton replied that work was rather slack with them then, and that every place was filled up. During the brief conversation that ensued, the blate young Scotchman, like most country lads in the presence of strangers, had some difficulty in knowing what to do with his hands, and unconsciously kept twirling his hat with them. Boulton's attention was directed to the twirling hat, which seemed to be of a peculiar make. It was not a felt hat, nor a cloth hat, nor a glazed hat; but it seemed to be painted, and composed of some unusual material. "That seems to be a curious sort of hat," said Boulton, looking at it more closely; "why, what is it made of?" "Timmer, sir," said Murdock, modestly. "Timmer! Do you mean to say that it is made of wood?" "Yes, sir." "Pray, *how* was it made?" "I turned it mysel', sir, in a bit lathey of my own making." Boulton looked at the young man again. He had risen a hundred degrees in his estimation. He was tall, good-looking, and of an open and ingenuous countenance; and that he had been able to turn a wooden hat for himself in a lathe of his own making was proof enough that he was a mechanic of no mean skill. "You may call again, my man," said Boulton. "Thank you, sir," said Murdock, giving his hat a final twirl.

When Murdock called again, he was at once put upon a trial job, after which he was entered as a regular hand. We learn from Boulton's memorandum-book that he was engaged for two years, at 15*s*. a week when at home, 17*s*. when from home, and 18*s*. when in London. Boulton's engagement of Murdock was amply justified by the result. Beginning as a common mechanic, he applied himself diligently and conscientiously to his work, and became trusted. More responsible duties were confided to him, and he strove to perform them to the best of his power. His industry and his skilfulness soon marked him for promotion, and he rose from grade to grade until he became Boulton and Watt's most trusted co-worker and adviser in all their mechanical undertakings of importance.

When Murdock went into Cornwall to take charge of the engines, he gave himself no rest until he had conquered their defects and put them in thorough working order. He devoted himself to his duties with a zeal and ability that completely won Watt's heart. He was so filled with his work, that when he had an important job in hand, he could scarcely sleep at nights for thinking of it. When the engine at Wheal Union was ready for starting, the people of the house at Redruth, in which Murdock lodged, were greatly disturbed one night by a strange noise in his room. Several heavy blows on the floor made them start from their beds, thinking the house was coming down. They rushed to Murdock's room, and there was he in his shirt, heaving away at the bed-post in his sleep, calling out, "Now she goes, lads! now she goes."

Murdock was not less successful in making his way with the Cornishmen with whom he was brought into daily contact; indeed he fought his way to their affections. One day at Chacewater, some half-dozen of the mining captains came into the engine-room, and began bullying him. This he could not stand, and adopted a bold expedient. He locked the door, and said, "Now then, you shall not leave this place until I have it fairly out with you." He selected the biggest, and put himself in a fighting attitude. The Cornishmen love fair play, and while the two engaged in battle, the others without interfering, looked on. The contest was soon over; for Murdock was a tall, powerful fellow, and speedily vanquished his opponent. The others, seeing the kind of man they had to deal with, made overtures of reconciliation; and they shook hands all round, and parted the best of friends."

ON WATER SUPPLY, ESPECIALLY TO SMALL TOWNS AND VILLAGES IN RURAL DISTRICTS.*

By J. Bailey Denton.

When it was first suggested to me to read a paper on this subject, it was at the close of September—perhaps the driest month on record—and at the end of a dry summer, following another drier still, in which the whole country had suffered from drought. The suggestion appeared to be so opportune, that I did not hesitate for a moment in acting upon it. Since that time we have experienced the wettest month (October) it has fallen to my lot to record since I have been an observer of rainfall. This coincidence would have made me hesitate in bringing the subject before the society, were it not that it aptly bears out one of the principal views I am about to advance, for to talk of the want of water, or to speak of water in any shape, immediately after experiencing the discomforts of excessive wetness, is to introduce my subject under forbidding circumstances. It may, therefore, be better to preface my observations by stating that the remedy for the present objectionable condition of the water supply of our small towns and villages in summer, which I am about to recommend, is the storage of water discharged in winter; and the appositeness of the great downfall of rain in October will be apparent when it is pointed out that if the quantity which has been allowed to run to waste during that single month, in the Midland and South-Eastern counties, had been stored for the use of next summer, the quantity collected would have alone afforded sufficient provision against a repetition of drought.

* Read before the Society of Arts.

Observers of meteorology know well that it is not the fall of rain that expresses the amount of water capable of storage, unless it be in exceptional instances, where the surface is exposed rock with steep inclinations. Evaporation and surface vegetation during spring and summer take to themselves a very large share of the rainfall, leaving little or none for other appropriation; whereas in autumn and winter, when these natural agencies are comparatively dormant, the reverse takes place, and in some months nearly all that falls is discharged from the surface into the rivers or absorbed by the earth. It is therefore quite possible to have a very dry summer with a rainfall above the mean quantity, if the number of wet days are comparatively few, and the general hygrometrical condition of the atmosphere such as to promote evaporation. The last seven months (from the 1st April to the 31st October) will serve to exemplify this effect very clearly.*

In the early months of April and June we had very little rain, and very few days on which rain fell, and vegetation being then in full vigour, and evaporation active, there was drawn from the ground very much more moisture than was deposited upon it in rain and dew. The quantity of rain, however, that fell in the intervening monthof May being quite up to the average, counteracted, to some extent, the deficiency of April and June. In July and August the rain was above the average, being increased by several heavy falls during thunder-storms, but such was the parched condition of the soil, and the thirsty state of vegetation, that the rain which rested on the surface was quickly absorbed and appropriated, while that which passed off replenished the ditches and ponds, and so furnished the poor of our rural districts with water, which they otherwise would not have had.

Thus partially replenished, we reached the month of September, in which there was literally no rain whatever in several of the South-Eastern counties, the only deposition of wet or moisture being dew, which was so heavy as to amount in some days to one ton weight and more per acre, an amount which admitted of being measured in the rain-gauge and recorded.

The total quantity of rain that fell on the eastern side of England, between the 1st April and the 30th September inclusive, may be illustrated by the following cases:—At York, the fall of rain was 10·7 inches, of which 5·3 inches fell in 19 days in August, and the remaining 5·4 inches was spread over 164 days. At Diss, in Norfolk, the quantity that fell was 12·4 inches, of which 9·3 inches fell in 30 days in July and August, and the remaining 3·1 inches in 153 days. At the Royal Observatory, Greenwich, the fall was 13·7 inches, of which 8·4 inches fell in 30 days in the months of May and August, and the remaining 5·3 inches in 153 days. These figures, as divided, will explain how it has been that, with more than an average fall of rain, we have had a dry summer.

If we turn to the West of England—that part of the country which has generally been supplied with rain in the proportion of 3 to 2—we find the rainfall of last year very little exceeded that of the East. It will be apparent, therefore, that the views and deductions about to be advanced will apply to the west as well as to the east, though in a less degree.

The quantity of rain that fell at Carlisle in the six months from 1st April to the 30th September was 12·4 inches, of which 8·7 inches fell in 35 days, and the remaining 3·7 inches in 148 days. At Manchester, the total fall was 13 inches, of which 10 inches fell in 54 days, and the remaining 3 in 129 days. At Helston, in Cornwall, the quantity which fell during the six months was 15·4 inches, of which 9·7 inches fell in 35 days, and the other 5·7 inches in 148 days.†

This was the condition of the country when the rains of October set in. The total quantity of rain which fell in this month will, of course, have varied with different localities, and it will be especially observed, when the records are examined, that the rainfall in the south and east of England exceeded that

* Some very remarkable facts will be observed in the meteorology of the present year when compared with the last and former years. The prevalence of east wind compared with that from the west has been about double the proportion generally due to it, and the same remark will apply to the quarter from which the rain came.

† It may be interesting to compare the various summer rainfalls quoted above with the rainfalls of last year and the mean falls of former years:—

of the north and west very considerably, and to a degree I believe never before recorded.

In Sussex the quantity that fell reached eleven inches, in Hertfordshire about six inches, in Suffolk about seven inches, and in Cornwall about eight inches; while in Lancashire it hardly reached five, and in Cheshire barely four inches.

Thus it will be seen that in one month, in which there were not more than 26 rainy days, the amount of rainfall was more than half the rainfall of the previous six months; and this large supply, it should be clearly remembered, was given us, not when vegetation was on the ground to seize it, and evaporation active to wrest it from us, but when harvest had cleared the ground of the crops, and the atmosphere was charged with moisture, leaving nearly the whole of the quantity at our disposal, if we had only taken the pains to intercept it.

It must occur to all who may think on this subject that the drought, which has been repeated for two summers, may occur again with equal if not increased effect, and the reflections which will arise to the mind in contemplating the sudden and copious supply with which we were replenished last month, cannot fail to suggest a remedy, even to the uninitiated in water questions.

The little I have said on the subject of rainfall must have shown how advantageous it would be if the country possessed a thorough system of recording rainfall and evaporation under proper authority, based upon equi-distant stations of observation, and not dependent on the spasmodic efforts of private individuals.

As an illustration of the truth of this remark, I believe I am right in stating that within these last two or three years the fall of rain on the Snowdonian range in North Wales has been discovered, by the efforts of Captain Mathew, of Wern, near Portmadoc, to be very considerable, forming, in fact, a source of supply which no one knew had existence. By a series of observations taken by Captain Mathew it is seen that in the past summer the rainfall of the region referred to amounted to 50 per cent. more than the greatest rainfall in any place of which records are published by the Registrar-general.

If Captain Mathew's figures were compared with the rainfall of the lake district of Cumberland, there would, I presume, be but little difference between them; and when it is remembered that Liverpool, after spending immense sums of money in storage reservoirs and wells, is without a proper quantity, that Chester possesses a very inferior supply, and that Birkenhead is dependent upon wells alone, the information supplied by Captain Mathew, though late in the annals of meteorological science, will be acknowledged to be of a most valuable character. When speaking of the deficiency of correct data, let me take this opportunity of expressing the obligation the public are under to Mr. G. J. Symons, for his great industry and perseverance in organising the best series of observations in the power of a private individual.

It is the opinion of many that various circumstances are at work to lessen the rainfall of this country, and to interfere with the influences which have hitherto prevailed, and there is doubtless much to support this view. Drainage in all its forms (agricultural or under-drainage, arterial or district-drainage, and the drainage of towns), the better and deeper cultivation of the soil by steam ploughing and stirring, and the clearing of woodland and worthless hedgerows, all help to reduce rainfall; and the multitude of railways which characterise localities may have the influence Mr. Glaisher attributes to them, of attracting downfalls under certain conditions of the atmosphere. But the sea-girt position of this country prevents a deficiency from being injuriously felt, for we have always close at hand an inexhaustible supply in the Atlantic Ocean, the North and Irish Seas, and the English Channel, from which the atmosphere can supply itself with moisture to any extent.

When admitting that the improved agricultural condition of the surface of the land owing to superior husbandry may be lessening the rainfall, though in an inappreciable degree, it is desirable to remove, if possible, the impression prevailing in the country that land drainage is helping to diminish the quantity of water discharged into our rivers. Nothing can be more erroneous than this view; the effect of all drainage is to increase the water discharged from the surface of the soil, but, unfortunately, it is discharged, not in summer when we want it, but in winter, when we have more than we want; and when, in its way to its ultimate destination, the sea, it often causes floods and damage to the lower lands and towns which exist on the banks of the rivers by which the accumulated waters pass away.

If we acknowledge that the object aimed at in all works of drainage, particularly under-drainage, is to discharge the excess, which would otherwise stagnate on the land and keep it in a state of saturation, until it eventually passed off by evaporation, it is clear that the quantity discharged is so much given to the rivers instead of to the atmosphere. The effect of underdraining, is to make the land absorbent, and allow the rain that falls on its surface to pass down into the soil, which yields up to the drains any excess that may exist after the retentive properties of the soil are satisfied. But it must not be supposed that this water descends from the surface of the land directly into the drains, as I am sorry to say many people think, but that it descends into the earth, and, having satisfied the demands of the soil, rises to the general level of the drains, when the excess passes away by them. The popular notion, that drains are placed in the ground to catch the descending rain, cannot be too soon removed: they are placed in the land to carry off that which would rise to the surface itself, were it not that the force of gravity is brought into action by the existence of the drains, which become so many channels for the discharge of the excess which the soil cannot retain.

It is stated by many, too, that the springs which found vent at the surface of the ground before drainage, are eradicated and lost by under-drainage, but this is not so; on the contrary, though removed out of sight, they are increased in volume. Before draining, the water which formed these springs rose to the surface, and was exposed to the sun and wind. The result was that a large proportion was dissipated by evaporation; whereas drainage prevents the springs rising to the surface, and thus lessens evaporation, whereby the flow of water through the drains is increased by the portion rescued from the atmosphere.

Thus it will be seen that, though the quantity of water evaporated from the surface is reduced by drainage, and thereby the source of rainfall proportionately weakened, the result is to augment in its aggregate quantity the discharge into the rivers. If the general effect of under-drainage is to increase in an irregular manner the water supply, there are points bearing upon our water economy which should have effect in governing the mode in which the works are carried out. It is not desirable to enter upon the mode in which drainage should be performed, but it is very desirable that it should be understood that the rate at which water is discharged from the land depends upon the nature of the drainage works. In under-drainage it depends upon the number of drains put into the soil; and in certain soils, if a greater number are adopted than are absolutely necessary for setting the water in motion, not only do they operate to the serious derangement of the river systems, but to the detriment of the productive powers of the land itself. There is not a shadow of doubt that much land of a free character is being drained by a uniform system of parallel drains, which, if differently treated, would be capable of advantageously sustaining instead of injuriously deranging the water supply—and this, too, with a better effect upon the productive capabilities of the land itself. It does not require an engineer nor an agriculturist to understand that clay lands should be drained in a different way to wet gravels and sands. A very large portion of the gravels and sands of this country are as wet as the clays, and are capable of becoming, by appropriate treatment, storage reservoirs themselves, to give out a good supply of the best of all water during summer, whereas, if they are to continue to be threaded and netted by drains, as they are now, the water hitherto stored by them will be discharged with increasing effect as drainage extends, attended by greater and more serious derangement of our river systems.

These remarks apply to underdrainage. There is another branch of drainage which, though at present affecting the water supply of rural districts in but a slight degree, will, as examples become more numerous, affect it very greatly. Our country is divided into numerous watersheds, drained by rivers, which flow down the main valleys, and are fed by tributary streams

Rainfall of the Six Months from 1st April to 30th September.

	1865.	1864.	Mean rainfall for several years.
	inches.	inches.	inches.
York	10 7	10·0	13·3
Diss	12·4	6·8	9·9
Royal Observatory	18 7	7·9	13·2
Carlisle	12·4	11·6	13·9
Manchester	13 0	15 8	17·7
Helston	15·4	9·3	15·35

English Winter Rainfall.

	York .. .. { above ground 6 inches. above sea level, 50 feet.				Wigston, Leicestershire .. .. { above ground 6 inches. above sea level, 220 feet.			
	1862-3.	1863-4.	1864-5.	Mean of 20 years.	1862-3.	1863-4.	1864-5.	Mean of 10 years.
October	2·80	3·13	2·57	2·49	2·91	3·07	1·66	2·93
November	83	1·85	2·45	1·99	·90	2·04	2·19	2·43
December	1·35	1·59	2·52	1·46	1·65	1·11	1·42	1.63
January	2·81	·82	1·07	1·72	2·88	·88	2·33	2·14
February	51	1·15	1·55	1·30	·48	1·71	2·43	1·21
March	1·11	1·78	1·18	1·35	·63	2·42	1·01	1·38
	9.41	10·32	11·35	10·31	9·45	11·23	11·04	11·72

	Orleton, Tenbury, Worcestershire { above ground 9 inches above sea level, 200 feet.				Goodamoor, Plymouth, Devon .. { above ground 2 inches. above sea level, 580 feet.			
	1862-3.	1863-4.	1864-5.	Mean of 29 years.	1862-3.	1863-4.	1864-5.	Mean of 10 years.
October	4·14	4·09	2·23	3·17	10·64	8·33	2·65	5·91
November	1·20	2·52	2·36	2·60	2·10	4·70	6·51	6·40
December	2·08	1·47	2·33	2 09	6·24	5·85	4·71	5·17
January	3·48	1·31	2·58	2·42	6·92	4·24	7·58	5·93
February	·82	1·73	2·66	1·67	2·56	3·51	5·68	4·11
March	1·11	2·51	1·13	1·79	3·56	2·99	3·91	5·11
	12·83	13·63	13·29	13·74	32·05	29·56	31·04	32·63

in minor valleys within the same watershed. Many of these minor valleys are waterlogged, and some few of them have already become the scene of operations, under the Drainage Act of 1861, by which they have been formed into drainage districts, and are discharging or are about to discharge the water which lodged in them with instant effect upon the main valleys below.

This is the object for which districts are formed. Before drainage, the water-logged valleys performed the part of so many reservoirs, feeding the atmosphere by evaporation, and the rivers by slow percolation, through the summer; now, after drainage, the water being discharged in winter as quickly as possible, it overloads the main channel, and collects in the lower valley, and not only does injury there, but interferes with the *régime* of the main rivers. Still, the drainage of such valleys is so beneficial and so profitable, that it will proceed in spite of difficulties; and it need not be repeated that the water thus discharged in winter, when it is injurious, is capable of being turned to use in summer when it is wanted.

It is not the object of this paper to dwell with any detail upon the sources upon which our perennial supplies, *i.e.*, our main rivers and deep wells, depend. All supply is gained primarily from the rainfall. The subterranean waters which find outlet by springs at the outcrop of different strata, and sustain our rivers and deep wells, are all fed from the surface by rain which descends during the winter months—from October to March inclusive—when as already mentioned, the demands of evaporation and vegetation are at a minimum. If the winter rains are less than the average, the subterranean supply is lowered in proportion, particularly if dry and hot summers intervene to cause an excess of evaporation.

For the last three winters we have been deficient in rainfall in several of the more important quarters of England, as will be seen by the following statement furnished by Mr. Symons; and it is a well-known fact that in those quarters the deep wells were never so low as at the present time. If the rainfall of the coming winter should not be sufficiently above the average to make up for past deficiency, the sequence of comparatively dry winters and summers, which have occurred since 1861, will tell with great force. (See Table above.)

The extent to which a succession of reduced rainfalls in winter act upon the springs and deep wells, is a subject to which I have recently given some attention, and I hope at some future time to publish the results. At present I can only state that measurements of wells, in the water-bearing strata, indicate with reliable accuracy that a succession of reduced rainfalls in winter, with intervening hot summers, lower the supplies beneath, and that any increase of fall in the summer does not raise the water level in any sensible degree.

This fact, and the experience gained in the use of deep wells, viz., that the increasing demand for water has already permanently lowered the water level in certain water-bearing strata, must have the effect of rendering such source of supply a doubtful one, and one of which the cost will increase as the wells multiply, so as to exclude their use for small towns and villages where economy is the first consideration. Many large towns, however, are now supplied by wells in the new red sandstone with excellent water; others by wells in the chalk and oolitic bands with water not free from objection.

It has already been shown that the effect of drainage is to reduce the flow of rivers in summer and augment them in winter. It will presently be seen, when treating of the increasing demands for water during summer, that circumstances conduce to depreciate the quality in an irresistible degree. It will suffice here to remark that all things are tending to the discontinuance, as a general rule, of the use of rivers as a means of supply of water for domestic purposes, although many large towns are dependent upon them. In exceptional cases tributary streams supply excellent water without any detracting effects; and springs taken at their source will always form envied objects by those who are seeking supplies for large towns, but they are seldom to be taken with impunity, for the simple reason that rivers are sustained by them.

Now let us consider to what extent water is used for social, agricultural, and commercial purposes; and how far those objects are likely to operate at that period of the year (summer) when the supply is least. We know from the published census the rate at which the population has increased, but we have no statistics by which we can arrive at the quantity of water used for household purposes, in contradistinction to the various ways in which it is consumed—in the factory, the steam-engine, the road, the farm, and the garden. As the population increases, the quantity supplied to each unit becomes greater too. With increasing cleanliness, water-closets are introduced into all places, and our smaller towns and villages are rivalling the larger towns and cities in the adoption of those comforts which necessitate an increased supply of water. As the weather gets warmer, and the natural supply less, the demand increases everywhere. The extended use of steam in manufactories, on railways, in the cultivation of the land, and in the duties of the farm homestead, and the use of water in watering roads and gardens, increase the demand, and, in the aggregate, swell it to a very large amount.

While the use of water is extending, and the summer supply becoming less by reduced rainfall and by the operations of man on the surface of the earth, to what extent are our rivers and streams being polluted? Is it not a fact that the water we apply to our household purposes is returned into the rivers, no longer as water but as sewage? This system of exchange is going on throughout the country, and, in spite of all efforts to prevent it, there does not appear to be any power to exclude from our rivers the liquid refuse of the surface. In fact, the most natural view that can be taken of the use of rivers is as the drains of the country through which they pass, for, although in the aboriginal state of the country, rivers were capable of supplying water for all the purposes for which it was then required, the condition of the country is so altered by increasing population and trade, that it is not a question whether the rivers should answer the combined purposes of supplying water and removing refuse, but how they can best serve their normal purposes as drains, and drains only.

It is not to be supposed from this remark that there are not some rivers which may still be maintained to all time as the sources from which to obtain water for all purposes, but these are the exception and not the rule; nor must it be supposed that we are to abandon the rivers to all the filth that may be poured into them, by which their limpid character shall be lost as one of the great charms of our rural scenery, but, it must be understood to mean that, though the rivers may be brought into an inoffensive condition capable of supporting fish, they cannot, as a rule, be made sufficiently pure to supply water to human beings.

It may appear presumptuous to speak so emphatically upon a matter on which so many opinions do and will exist, but when it is mentioned that all that has yet been practically done in the way of purifying sewage has failed to do more than separate the solid from the liquid, leaving the liquid as noxious as before, the presumption will not appear so great. Science may eventually discover some means of appropriating the fertilising gases of sewage, which, when once mixed with water, according to our present knowledge, are inseparable from it. When that time arrives, a somewhat different view of the matter may be taken, but under any circumstances the principal purpose of rivers will remain the same, and the liquid refuse, after utilisation, must find its way into them, and therefore will necessitate their being maintained as drains.

The shifts to which towns are already reduced in order to obtain water and discharge their refuse at the same time may be appropriately illustrated by an instance, the particulars of which can be verified. The case is that of Tunbridge Wells, in Kent. I especially select that town because it is one of modern existence, and therefore fairly illustrates what may arise in other places where no towns exist.

Tunbridge Wells is now a large town abounding in first-class houses; indeed it is hardly possible to mention any town containing the same proportion of superior dwellings. These houses are furnished with water-closets, and all the refined appliances requiring a large supply of water. To furnish that supply has been a very difficult matter. In the first instance the springs,—which burst out on the present site of the town, and flowed by a small channel into the Medway (some five miles off), providing the population along its banks, such as it was, with excellent water,—were intercepted at their head, and appropriated, for the purpose. This water, after serving the houses, for which it was abstracted, was returned in its polluted state into its old channel, and thus it flowed to the Medway a foul and corrupted sewer. So sensible were the landowners at Tunbridge Wells of the value of the springs they had appropriated, that, for fear they might be affected by any operations on the part of those to whom land was sold or let, covenants were introduced into deeds of sale or lease, prohibiting the parties from dealing with the property in any way that could affect these springs. The supply so secured and protected is now found to be insufficient, and last year the authorities applied to Parliament for powers to extract springs from lands some distance away, and thereby absorb streams not in the valley of which Tunbridge Wells is the head, but in an adjoining valley, from which the water, when taken, will have to be raised over interposing high ground to a supply reservoir near Tunbridge Wells.

Last year an effort was made by the authorities of the town of Cheltenham to extract springs which were some of the sources of the river Thames; and, had it not been that the Thames was a metropolitan river, there is no doubt that the evil would have been consummated, and the villages and smaller places would have raised their voices in vain. This compound system of injury, first, in taking water from poor districts to supply the rich, and next, giving them in return the discharged sewage, will of necessity be partially remedied, for it is altogether against public justice that such a system should remain unabated. But it must not be imagined that a modification which extends simply to the separation, by processes of deodorisation and filtration, of the solid matter from the liquid sewage, so as to allow the latter to pass away clear into the river, or that surface irrigation will restore purity.

A single instance will illustrate this, and the case of Barnard v. Arkwright will serve very well for the purpose. The plaintiff, Mr. Barnard, was a farmer, using the Harlow Brook, in Essex, as a watering place for his cattle. Into this brook the washings of the kennels of the Essex hounds were discharged. The washings were particularly objectionable, because it was found, in certain instances, that the dogs had been fed on horses that had been glandered, and that the skins of the dogs were occasionally washed with arsenic, so that two poisons found their way in some shape or other into the brook. It was stated by the plaintiff that his horses and cattle had been killed by drinking the brook water, which the defendant denied, and an action therefore was brought. The case was tried, and the court made an order that the objectionable refuse should not be discharged into the brook. The master of the hounds, upon receiving the order, set to work to filter and precipitate the refuse, and, having made it clear, assumed that he had obeyed the order. The tenant in question did not concur in this view, and I was directed by the court to see if the order had been obeyed. When I visited the spot, the filtered liquid was perfectly clear, but, suspecting that it might still be obnoxious, I obtained the assistance of Dr. Voelcker to analyse it, and he took several bottles of the clear water away with him to his laboratory at Cirencester. The water was left in the corked bottles for a few days, but when at length the doctor opened them, in the presence of his pupils, to perform the analysis, the stench was so great that everybody had to retire from the laboratory to avoid it. The filtered refuse was as impure as ever.

If we travel northwards, into the manufacturing districts, we there see the streams, which, in their aboriginal state, were limpid and pure, partake of all the colours of the rainbow, and tainted in every degree of impurity. These facts are not encouraging for the use of river-water for domestic purposes; and, taking a general view of the future—as well as the present state of things—it can hardly be expected that any amount of improvements can render the rivers generally fit for such purposes, however they may be improved as arterial drains. If it were necessary to adduce further proof in support of this view, the application of sewage as manure to the surface of farm land would be sufficient in itself to satisfy any doubt, for although a large proportion of the manurial elements will be absorbed by the soil, there will still remain on the surface a proportion to be washed off by storms and otherwise, which will taint the rivers very objectionably, and will necessarily become greater as sewage irrigation extends.

That wells are too costly and too precarious a source, and rivers too foul and already too much reduced in volume to serve commonly as sources of water supply, is not an original view. The General Board of Health, in 1850, rejected the two sources of rivers and wells as a means of supplying the metropolis, and recommended the storage of drainage water instead. It is not necessary to endorse the views of the Board of Health in their application of this system to the metropolis, as the assumptions on which they were based have not stood the test of subsequent experience; but in a modified shape the views of the Board appear applicable, especially to small towns and villages in rural districts. The collection of surface water in reservoirs before it reaches the rivers has been most successfully carried out in many of our larger towns in the north, viz., Greenock, Glasgow, Bolton, Liverprol, Manchester, Oldham, and many others. All have their gathering grounds and reservoirs, and although some of these towns have been on short supply this last summer, yet there is little doubt but that, such as the supply has been, it was better than could have been obtained from other sources.

These northern towns, however, have contented themselves with collecting the water from the surface only; in no instance, that I am aware of, has it been thought necessary to resort to under-drainage as a means of increasing and purifying the supply, as the gathering grounds have been in rocky districts of the primary formation, and the water collected has been sufficiently pure without it. But this superior condition of surface formation applies to a small proportion of England only. It is with the flatter districts, upon which small rural towns and villages are numerous, that we have at present to deal; and I will now endeavour to show how, by the storage of surface and drainage water, they may be furnished with water in the driest summer.

There are few small towns and villages which have not in their origin had some reference to the existence of water in the shape of a spring or a stream. If it be a spring of sufficient volume it may be hardly possible to improve the supply, though as compared with the water of drainage it may be hard and inferior. If it be a stream of like sufficiency, untainted by sewage and manufactories, the same remark may apply; but if the stream has become impure by the extension of trade, by the use of water-closets, or by any other mode of defilement, the only question that will arise before rejecting it will be whether there are not times during the winter season in which the impurity becomes so small by the dilution of rainfall, that, with the help of strainers and filters, a sufficiency of the improved supply may be collected and preserved for summer use. It is more than probable that an examination of the facts in many cases would show that this could be readily done. When the relative height of the brook and the town will not allow of a reservoir being filled directly by the former, recourse can be had to a wheel or ram to raise in winter the summer supply. The best formed hydraulic rams, made by Easton and Amos, or Freeman Rowe, with an available fall in the stream of 7 feet, will raise to the height of 30 feet one-eighth of the quantity that sets them in motion, and assuming a reservoir formed above the village to receive the water raised, a stream discharging 23 gallons per minute during the winter and spring, will be sufficient to raise in 180 days 720,000 gallons for use during the summer and autumn. A turbine, or an overshot wheel, might take the place of the ram with advantage when the quantity of water to be raised is greater than that stated. But of course the expense of either ram or wheel and attendant works would be saved in those instances where water can be brought from a height and conducted at once into the service reservoir, with an overflow to discharge the excess when the reservoir is filled. But in many instances, even where streams exist, a better supply may be obtained by the underdrainage of land in the neighbourhood; and if we resort to it, we have data which will quite satisfy the most fastidious inquirer, showing that the minimum discharge will afford a sufficient quantity of the very best water, if the area of drained land be sufficient. It is surprising, too, how few acres of land will suffice for the purpose.

When land is underdrained at sufficient depth (that is, 4 feet at least) the drains generally commence running in the month of October, and cease to run about the end of May. The proportion of the rainfall which the drains will discharge in that period will necessarily depend upon the nature of the drained land, for the larger the proportion of sand or gravel the more quickly will the rain be absorbed and discharged, and the larger will be the quantity available. In reverse degree will this be the case when the soil is clay—the denser it is the less will be discharged. The proportion discharged will vary (according to the qualities explained) from more than two-thirds to about one-fourth of the rainfall; thus, with a winter fall of 10 inches of rain and snow, when the latter is melted the maximum may be taken at 160,000 gallons per acre, and the minimum at 60,000 gallons per acre for every acre drained. The mean discharge of drained lands may be fairly taken at 100,000 gallons per acre. The water of underdrainage is free from all animal and vegetable matter, for the four feet of soil through which it passes absorbs all the ammoniacal matter, and, in fact, forms the best chemical filterer that is known.

Analyses made of drainage waters with a view to ascertain their value for domestic purposes have exhibited most conclusive proofs of their superiority over other supplies, when to purity is added the quality of softness, which, for household uses, is a great desideratum. In this particular all evidence supports the conclusions come to by the Board of Health in 1850, but the quantity that the Commissioners assumed would be available is not supported by experience, and therefore it is that, except in a very few cases, the water of drainage may not be found applicable to large towns, though specially suitable for small ones.

If we apply the system of storing drainage water for the supply of villages in summer, we may test the question in its monetary aspect by assuming the average population of rural villages to be 400. If each inhabitant requires 10 gallons of water per diem (a quantity quite sufficient in places where the water-closet system does not wholly prevail) it will require a supply of 480,000 gallons for the summer. This quantity is taken on the assumption that for 120 days, or four months in the year, there will not be a supply from ordinary sources. To secure this net quantity, a considerable allowance must be made for waste by evaporation, and 50 per cent. on the quantity required should be added to meet this loss. A reservoir, or basin, to hold 720,000 gallons will, therefore, be required, and this quantity of water must be stored.

It requires very little calculation to show that if an acre of land, during the period of discharge will yield 100,000 gallons, it required less than 7½ acres to yield the required quantity for 400 persons, or 12 acres of land where the soil is of the densest character. These numbers of acres would have to be increased where the rainfall is so far below the average that a minimum quantity of ten inches cannot be depended upon during the discharging period. The reservoirs necessary to hold 720,000 gallons would be rather more than 4-10ths of an acre, if the depth were 7½ feet. This extent is too large for covering at a cost moderate enough for village economy, and therefore the probability is that open ponds will take the place of reservoirs, if they could be made in some convenient place above the village, and could be shaded from the sun and protected from the wind. The expense of making the pond, using the earth to embank it, and planting the embankment so as to exclude as much as possible sun and wind, and thereby to reduce evaporation and preserve the purity of the water, would be about £415.

Assuming these figures to fairly represent the cost of supplying a village of 400 inhabitants with water, and the number of houses or cottages in the village to be 100, it follows that the cost per person would be £1 0*s*. 9*d*., and the cost per house £4 3*s*. If the cost were charged upon the houses, and the money were borrowed to do the work, it could be repaid by instalments with interest in thirty years at 6½ per cent., and the annual charge would amount to £26, or a charge upon each house of not quite 5*s*. 3*d*. per annum.

The capability of thus supplying villages with water is not conjectural;—every day's experience in drainage only confirms the conclusion that there are few villages in which something of the sort might not be devised. In fact, the figures given represent the worst aspect of the suggestion, for nature frequently affords opportunities of collecting the water of drainage without recourse to artificial ponds, in hollows and ready-made receptacles which may be appropriated with advantage.

Of course it is assumed that there are lands above the village which require drainage and would supply the required water, and that the reservoir shall be so much above the village, that by means of iron pipes, with stand-pipes and taps, the water could be delivered down the street at convenient places, for the use of the poor.

At present legal powers do not exist enabling cottage owners in villages to charge their properties with the cost of water-supply. But this question is one of detail only, which will be met when the object is recognised as one worthy of legislation.

In closing this paper, which I am well aware is very deficient in detail, I trust I may be allowed to express the hope that I have stated enough to attract public attention generally to the important matter of the water economy of our country, and to that of the rural districts and villages in particular.

I regard drainage in its various branches in conjunction with those natural sources which are beyond the reach of defilement, as the most simple and certain means of furnishing a pure supply. This view is based on the broad facts, 1st, that of the 20000,000 of inhabitants in England and Wales, about one-third, or perhaps 7,000,000 may be considered to be scattered over the face of the country in small towns and villages; 2nd, that whereas there are at least 16,000,000 acres of wet land in England which require draining, if they are not already drained, it would only require the water of drainage from less than 250,000 acres to supply the whole of that population with water in summer; and 3rd, that this water, which is the best of all water, is *created* by drainage, inasmuch as it would be evaporated from the surface if drainage did not discharge it.

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D.

E.

F.

LIST OF PLATE ENGRAVINGS.

Kim

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