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The Editor will be glad to receive MS. articles and also illustrations of current architecture in this country and abroad with a view to publication. Though every care will be taken, the Editor cannot hold himself responsible for material sent him.

THURSDAY, DECEMBER 12, 1940. NUMBER 2395 : VOLUME 92

PRINCIPAL CONTENTS

Owing to the paper shortage the JOURNAL, *in common with all other papers, is now only supplied to newsagents on a "firm order" basis. This means that newsagents are now unable to supply the* JOURNAL *except to a client's definite order.*

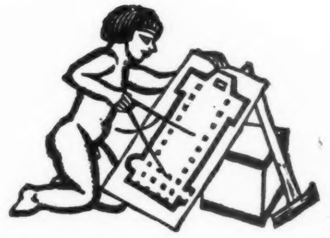
To obtain your copy of the JOURNAL *you must therefore either place a definite order with your newsagent or send a subscription order to the Publishers.*

GRANARIES AT TRONDHEIM

The timber granaries lining the harbour at Trondheim, Norway, are built entirely on wood piles and are painted in various shades of orange, red and yellow.

WINDOW DETAIL AT STOCKHOLM

Bay windows to living-rooms in a working-class flat block designed by Backström Reinius. The windows are faced with oiled teak on a breeze backing. The sashes slide vertically on special metal guides and despite their width of seven feet can easily be moved with one hand. Inner sashes are hinged at the top and can, on the release of a catch, be turned up through a right angle to facilitate cleaning.



GLASS

IT has been stated officially that an appreciable proportion of air-raid casualties have been caused by flying glass. In addition, it has become plain to all architects since heavy bombing began that glass broken by blast has caused, directly or indirectly, great damage to goods and plant and great loss of working time. It therefore seems somewhat surprising that precautionary measures should not have been taken on a far wider scale.

As regards the mass of buildings—houses, small shops, small offices—this inaction seems to have three main causes: bombs cannot fall everywhere, and owners hope they will be lucky; it is becoming more generally known that no protective device will increase the resistance of a piece of glass to blast; and the average man cannot be bothered or cannot afford to take proper precautions against the consequences of broken glass.

But the situation concerning offices, shops and places of public resort in the centre of towns and all larger buildings near military objectives seems very different. Damage to unprotected glazing in such buildings may not only cause casualties, it may also result in damage to goods, plant and documents, and so interrupt business and production. In very many cases it has done so, and there would seem very good reason for insisting that the occupants of such buildings should take reasonable measures of protection.

The tests described and illustrated in this issue show that methods of window protection against blast fall into four main groups. The simplest method is the provision of internal wire mesh screens with a supply of glass substitutes or new glass kept ready to provide weather protection. The second method is the substitution of wired or toughened glass for existing common glass: in shop windows this method can be combined with the boarding up of part of the area formerly occupied by plate glass. The third method is the provision of shutters which can be closed in times of danger or after dark as a blackout device. The fourth is the use of glass-concrete construction which possesses a very high degree of resistance against blast and debris and considerable resistance to bomb splinters.

For most business and commercial buildings wire netting would seem to be the cheapest and easiest form of protection. The common window type which is an exception to the wire-netting rule is the large plate glass window. Shopkeepers object to wire mesh because it obscures the view of their goods, and it has the further disadvantage that, if the glass is broken, a new front will have to be fitted whether netting is there or not. The sensible solution to this problem is to remove the plate glass, reduce the size of the opening and glaze small displays with wired or other strong glass. And shops near the centres of larger towns are so likely to have their windows broken before the end of this war that such a substitution, in view of the high cost of plate glass windows, would seem no more than a wise investment.

And if the protection of all larger buildings against glass damage would be wise, the full protection of all buildings concerned with war production would seem essential. A bomb may fall near a factory and injure no one, but the consequences of broken glass may seriously retard production.

The protection of existing factories against the results of broken glass is linked up with problems of ventilation and lighting, and the best protective scheme for each part of an existing factory depends on the structural and other conditions which exist there. The removal of internal glass and the provision of light weatherproof screens for vertical glazing are precautions which have been taken in most factories. The treatment of roof lights is more difficult. Many factories have combined weather protection with a blackout by covering all roof lights with hessian-bitumen sheeting. This method has the virtue of requiring no attention or manipulation once it is up. But if one considers that roof glazing is not very vulnerable to blast from a bomb bursting on the ground and that working perpetually in artificial light cannot be good for anyone, sliding shutters or wired glass with wire netting and roller blinds beneath are much to be preferred.

Lastly, one comes to new buildings—of which in wartime a large part will be factories. Here, at least, the architect or engineer can escape from make-shift and adaptation and use the methods which it is known for certain will reduce glass damage to a minimum. The factories will be on one floor and as widely spread as possible. Walls, internal as well as external, up to a height of nine feet or so will be blast- and splinter-resisting, and main framing will be rigid: but the upper parts of walls and the roofs will be filled in with light standardized panels.

Roof glazing will be of wired glass, with roller blind or light shutter blackout and wire netting below. Rooms containing valuable mechanism will have no windows or, if used for fine work, will have glass-concrete roof glazing. In addition, a stock of spare materials for wall and roof panels and the labour to fix them will be kept ready in each factory.

By these measures the danger of damaged glass causing a serious hold-up in production can be almost wholly banished from new factories.

The Architects' Journal
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NOTES & TOPICS

BIG SHELTERS, SMALL SHELTERS . . .

IT was announced last week that we are going to enjoy another official publicity campaign : this time to make us appreciate small shelters. I do not deride official publicity campaigns. Most of them are much better run than private campaigns (for example, the Ministry of Food's notes for housewives). But I have doubts about the small shelters campaign in so far as it is designed to coax people out of large shelters.

*

I stated last week that, in my belief, it would be far easier to improve conditions in large shelters by the conversion of framed buildings into additional shelters than to do so by the improvement of surface shelters—which at present are the only alternative to Tubes and large basements for most of those who shelter in such places. From a health point of view—given equal conditions—it is no doubt better to have people in small groups than in large congregations. But when one thinks of the present conditions of the shelters which the small groups are to be coaxed into occupying, and the work and supervision which will be needed to make them tolerable and keep them tolerable as sleeping shelters, large shelters begin to have manifest advantages.

*

Let us suppose the average brick surface shelter can be converted into a sleeping shelter for 40 people. To cater for 200,000 people, 5,000 separate conversion jobs must be carried out and 5,000 relays of wardens or shelter marshals must be arranged to keep the shelters clean and maintain discipline and the blackout. The resulting problems of heating, lighting and sanitation are such that I make no excuse for restating that to me it seems easier to commandeer and convert 500 framed buildings for 400 people each. And this leaves out of account the reason which takes many people into large shelters—that it is far easier to put up with the Blitz in a lighted space and numerous company than alone in an Anderson with the wife and children. Cut out the noise and most of the Blitz's terrors are gone.

. . . AND THE ALTERNATIVE

Lord Horder's Committee recommended three main methods of improving conditions in large shelters : coaxing people into small shelters, evacuation, and improving large shelters.

*

A few days ago I spent some hours with a local billeting officer, and was left in no doubt that conditions in reception areas would have to be much improved before Solution No. 2 would become popular either with those who go or those who receive.

*

My informant seemed to me admirably suited for his job. He was a retired business man who had spent his life in North London, and since his retirement had competed for prize marrows with his country neighbours. He thus knew the habits and prejudices of both town and country.

*

He made no bones about the distastefulness of his new work. A portion of his country acquaintance did not attempt to disguise that they relied upon their friendship with him to save them from evacuees ; another portion, having exhausted lists of imaginary relatives who were about to descend on them, threatened him bluntly with lasting enmity if he planted so much as a child on them.

*

But this behaviour among those who should know better was the least of his troubles. The chief difficulties arose from the small size of the receiving houses, and lack of employment for evacuee mothers. A typical evacuee mother with a baby and a child of school age had three alternative employments during daylight hours : interweaving washing and feeding her children as best she could with the arrangements of the receiving family ; walking about in a place where she knew no one ; and (in good cases) sitting in a small unheated bedroom.

*

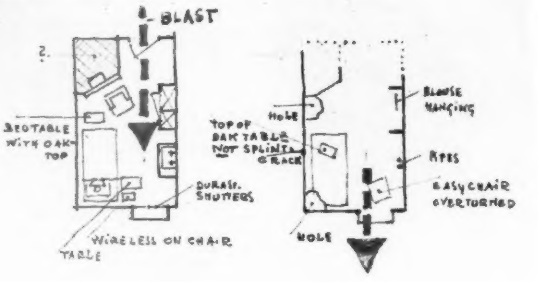
My informant believed that if evacuation is to be increased and made tolerable for the rest of the war, the responsibility of the evacuating authority must not cease at Waterloo nor that of the receiving authority when the evacuee is billeted. He was emphatic that the strain on evacuees and receiving families must be diminished in three ways. First, all evacuees from one street must go to the same place. Second, there must be a tolerably equipped meeting place where evacuee mothers can meet and pass the day. Third, there must be nursery schools where evacuee babies can be washed, fed and looked after for part if not all of the day.

BLITZ CLOSE-UP

A note on this page several weeks ago, in which I mentioned that a bomb had exploded about two hundred yards away from me, seems to have been taken by several readers as a challenge. I therefore must make clear that it was not : we all know by this time that many people are able to tell the story of having met the Blitz at much closer quarters.

*

But I may add that probably few have met it at closer quarters than one of those who have written to me. This correspondent, a woman architect, tells a story of technical as well as human interest. She was in bed on the second floor of a modern framed building of seven reinforced



concrete floors and strong partitions, when a bomb—calculated to be of about 300–400 lbs. weight—burst in a lift shaft about 40 ft. away from and perhaps 10 ft. below her room.

★

Her room was swept almost clean by blast, as the *Before* and *After* sketches show (the complete disappearance of a fitted wash-hand basin should be noticed), and the floor was heaped with debris. But the bed, and its occupant, remained *in situ*. My correspondent suggests that the only rational explanation of her survival was that the structure behind the fireplace was solid enough to screen her and the bed from the blast.

★

This explanation seems so probable that architects who live in framed buildings may feel inclined to place their beds against the most solid wall or other structure which they can find.

THOSE GRAND OLD FOREFATHERS

Less than middle-aged architects who, like myself, spring from architectural families, have had in youth to put up with many homilies on the shoddiness of modern construction.

★

Scores of times we have heard our elders cry out at 11-in. hollow walls and steel-framed buildings veneered with stone and the rest. " Frames ! . . . " those elders used to exclaim, as they warmed to the good work—" Wren and Vanbrugh didn't need frames. Their *walls* took the load and stood foursquare to the weather and wind. And I mean to go on copying the good old builders as far as I can, and build to *last !* ". . . and so forth.

★

My part in London's Civil Defence has not been a large one and I like a bad air raid no more than the next man. But the badness of the Blitz had never failed to be submerged in my thoughts, when I arrived before another ruin, by my desire to have Uncle George, or any other of the old frauds, there to look.

★

Built foursquare, built to last—my foot. Nothing built in a town since 1900 and precious little spread along seashores since 1919 can equal the universal and abysmal shoddiness of our grand old forefathers' construction. And I do not write of " slum " buildings. I have seen the foursquare brick front of a porticoed Bloomsbury mansion ripped off to reveal itself $4\frac{1}{2}$ in. thick with a kind of pale fence of lath and plaster behind. I have seen mere trimmings off logs of about 3 by 2 scantling spanning 12 ft. as floor joists, and a 9-in. wall of crumbling bricks, with little pats of lime mortar under the perpends, backing up the glistening painted stucco of a £2,000-a-year Regency house not so far from Regent's Park.

★

This war has provided many showdowns, but none more complete than that of our forefathers' construction. The jerrybuilder of the 1930's could only learn one thing from his great-grandfather—that he had not so far even begun to act up to the slogan, " What isn't seen, doesn't matter."

★

What is more, if those forefathers and my architectural relatives were in London now, I have no doubts about their behaviour. They would one and all cut a dead straight line for a big steel-framed building—and never mind about the thickness of the stone on the front. The Blitz makes realists of us all.

FACTOR OF SAFETY

The large garage and service station beside which I was waiting gaped rooflessly heavenwards and a dejected man was locking the little office at the entrance. My bus was late.

★

" H.E. ? " I enquired casually.

The dejected man lit a cigarette.

" Not this time," he replied. " Last January, it happened. Collapse, it was."

★

I brightened up. A thing like that took one back to the good old days when one had to read Belgian building papers to hear of a good collapse. I asked for more.

★

" Yes—s," said my companion, " it was only completed in August before the war. They used a new type of one-span roof—a boxy sort of thing which the boss discovered. It was O.K.—no pillars at all—till the snow came last January. We were full at the time, too."

" Quite a row, I suppose ? "

" Yes. The owners of cars were mad enough when we told them they garaged at their own risk. So was the boss : I remember him and the architect and builders here the next afternoon. A play it was ! "

" What did the architect say ? "

" I don't know—but it was all on the people who built the roof. The boss . . ."—my companion grinned drearily —" has a claim ready for them as long as your arm."

" Ready for them ? . . . Has he lost their address or something ? "

★

" No—not at all. He's got their address all right. But it's at Hamburg."

ASTRAGAL

INFORMATION CENTRE

The publication of " Glass in Wartime " in this issue has made it necessary to omit the Questions and Answers of the Information Centre. These and other contents of the JOURNAL *will be published as usual next week.*

NEWS

●

WARTIME BUILDING

The design and erection of wartime buildings are dealt with in Wartime Building Bulletin No. 10, just issued by the Department of Scientific and Industrial Research (H.M. Stationery Office, price 1s.). The bulletin is intended to assist the designer in the preliminary stages of a wartime building project. Notes on concealment and the minimizing of damage through air attack are contributed by Technical Branches of the Ministry of Home Security. Some suggestions on how to start saving timber are given in a section written by the Forest Products Research Laboratory of the Department of Scientific and Industrial Research. Information about economy in the use of the other materials was obtained while preparing earlier bulletins in this series. Slight modifications are made to the factory type designs in structural steelwork (Bulletins Nos. 1 and 4) to include recent recommendations made by the Research and Experiment Branch, Ministry of Home Security, based on the experience of recent air attacks.

EXHIBITION OF WELSH STUDENTS' WORK

The annual exhibition of the Welsh School of Architecture was held in the Technical College, Cardiff, on November 21. Mr. John Bishop, A.R.I.B.A., Chairman of the Central Branch of the South Wales Institute of Architects, presided, and the Lord Mayor of Cardiff (Alderman C. H. McCale) declared the exhibition open. In his opening remarks the chairman stated that he had had the privilege of passing through the five years' full-time day course in the Welsh School of Architecture.

The Lord Mayor, in declaring the exhibition open, said he had been privileged to be connected with the Technical College for 18 years, during which time the College, in which the Department of Architecture had played a prominent part, had made tremendous strides.

Mr. W. S. Purchon, M.A., F.R.I.B.A., Head of the school, gave an address on the work of the school during the previous session, at the close of which six students were awarded the College Diploma in Architecture, and eleven the Certificate. One of the students, Mr. D. C. Williams, was awarded the Dawnay Scholarship for that session, Miss Mary Morgan the Banister Fletcher Essay Prize, and W. J. Phillips a Certificate of Honourable Mention. The school has won the Essay Prize on two occasions and has secured three of the nine Honourable Mentions.

Mr. Purchon also referred to the work of the School of Architecture Club, to visits paid to local buildings in the course of erection and to the sketching and measuring of buildings of architectural interest during the summer vacation.

A vote of thanks to the Lord Mayor and the Chairman was proposed by Councillor C. G. Moreland, M.B.E., and seconded by Mr. T. Alwyn Lloyd, J.P., F.R.I.B.A., P.P.T.P.I., who emphasized the importance of planning for the future during the war. Otherwise, he said, there would be great danger of reconstruction after the war being carried out without adequate opportunities for full consideration.

CHANGES OF ADDRESS

Mr. Julian Leathart, F.R.I.B.A., has moved his office to The Cottage, Jenkins Hill, Bagshot, Surrey. Tel.: Bagshot 281.

All communications for Messrs. Samuel and Harding, AA.R.I.B.A., should be addressed to Capt. G. H. Samuel, R.E., 32 Porchester Terrace, London, W.2.

The office of Messrs. W. H. Saunders and Son, architects, consulting structural engineers and surveyors, has been transferred to "Deerhurst," Sarisbury Court, Sarisbury Green, Hants. Tel. No.: Locksheath 295.

Mr. Frederick Gibberd, F.R.I.B.A., A.I.A.A., has changed his addresses to: Country—Northaw, Herts (Tel.: Barnet 6041); Town: 34 Red Lion Square, W.C.1. (Tel.: Chancery 8171).

Messrs. Callender's Cable and Construction Co., Ltd., have removed their Bristol office and local sales office and stores to 51 Queen Charlotte Street, Bristol.

PROBLEMS OF BUILDING RECONSTRUCTION*

By D. E. GIBSON
City Architect, Coventry

Presuming, as we must, that the outcome of this war will be the same as the last, it is only reasonable to suppose that similar problems will occur again, but in some cases in an aggravated form. The housing problem will be even more acute and, whatever the financial state of the country, housing and other building schemes will have to go on, because they employ so much labour and involve so many varied trades.

When this rebuilding takes place there must be an ultimate plan in view, and, as planning takes time, it is evident that at least some of the thinking should be done now. As a material ideal we should postulate the right of every man and woman to a healthy and beautiful environment. This cannot be acquired merely by local planning, but national planning is also required, so that the first step should be the formation of a full-time committee of highly trained planners in possession of such knowledge as already exists, such for instance as the report of the Commission for Industrial Distribution of the Population, the relevant P.E.P. Report, and the report of the proposed Severn Barrage Scheme. This committee should have the widest powers possible in wartime, and no vested interest should be allowed to withhold from it information necessary for the preparation of a long-term national plan. To assist this central committee, every town should have in its architect's department a group of town planners, preparing a local survey from which a comprehensive plan could be constructed.

At present there is a tendency for populations to converge on a few great centres, leaving the countryside and its natural industries to decay. I believe that this movement is wrong, and I would like to see a reversal of this present tendency. It should be possible, with the grid and cheap electricity, to have a network of clean healthy towns, small enough for every man to be within calling distance of the country, and yet large enough to provide collective facilities for decent cultured living. The towns would aim at consuming as much as possible of the products of their local region. In this way the towns and country, so long divorced, would be regenerated. The keynote of the planning committees to which I have referred should be decentralization and regeneration.

It will take some time to work out all the details of the major problems, and in the meantime there will be the immediate post-war problems to be considered. There will be a shortage of labour because of the tremendous volume of the work proceeding, and an even greater shortage of skilled labour, owing to the wartime diversion of building operatives into the factories and the services, with a consequent loss of craftsmanship. There will also be a shortage of certain materials, which it will be impossible to import rapidly enough.

Some of the problems to which I have referred above are already presenting themselves in war-time building which is proceeding at present in Coventry.

An entirely new idea has been the provision of an air-raid shelter inside the house and opening into the kitchen. The walls are of 14 in. solid brickwork and it has two layers of reinforced concrete over it. It is big enough to take full-sized mattresses and these can be fitted one above the other like bunks. A ventilator has been provided, and if poison gas should be used the inlet could be fitted with a small gas filter in the fan. As the shelters are built into the houses and as the houses are in blocks of four and six, the adjoining walls act as buttresses which should give the shelters additional support.

In the general appearance as seen from the road, the design of the houses has been carefully considered, and some of the garden sheds have been brought to the front to form an interesting link between the blocks of houses, and have the advantage that they can be used as garages for small cars or motor cycles. Good features of the English village, such as a strip of common lawn between the houses and the roads, have been introduced, instead of the disordered appearance of many small front gardens.

* Extracts from a Paper read before the Royal Society of Arts on December 4. Mr. W. H. Ansell, P.R.I.B.A., presided.

THE JOURNAL IN WARTIME

The illustrations of a number of buildings which have been published in the JOURNAL *during recent months have been unaccompanied by plans, and in other cases the photographs reproduced have not done justice to their subject.*

In regretting these deficiencies the JOURNAL *asks its readers to bear in mind that the restrictions of the Censor are not confined to the daily press, and that the difficulties of an architectural photographer are at present many, and include the risk of physical injury from over-patriotic local inhabitants.*

Steel casements in an area after having been pulled from a fourth floor window by the suction wave of a near miss. Most of the wired glass has remained in the frames after the explosion and a forty-foot fall.

GLASS IN WARTIME

Being a survey of the problems arising from the tendency of glass to fly or break under blast action, of the comparative resistance to blast of different glass types, and of the precautions which are obligatory or advisable in various types of building

GLASS in Wartime is a phrase which suggests a reliable friend who has suddenly become homicidal. Up to the outbreak of the war almost every week saw glass being put to new uses. Domestically it had appeared in new forms as ash-trays, cooking dishes, table ware, bell pushes, table tops and, in at least one case, as a couch. Decoratively, it had progressed from being a wall finish to a floor finish and being the whole of a door. In shops it was becoming more and more the sole material used for finishes and fittings. It had appeared as a fabric and was likely to be used for frocks. In special forms it had been made fire-resisting and bullet-proof, very nearly unbreakable and highly resilient. There seemed no end to what could be and would be made of glass.

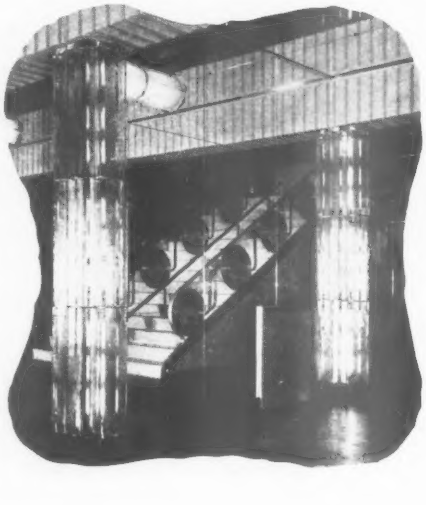
With the outbreak of war all this changed. The man in the street ceased to welcome more glass and began to turn an apprehensive eye on what he already had. Official publications emphasized the danger of flying glass during air raids and urged that precautions should be taken. Ghoulish photographs of what glass had done in the Spanish war were seen by a few and their details passed on to many more with such added trimmings as were calculated to make the maximum impression. For the private individual, protecting glass against splintering was a nuisance and an expense; to the shopkeeper, it seemed that he must either pay money to remove or protect expensive windows, and thereby risk losing trade by the obscuration of his displays, or risk injuries and the loss of far more trade if they were broken.

The dilemma was universal and was increased by the unpredictable behaviour of glass under blast pressure, the long period of " phoney " war, and the host of protective devices on the market—some of which were said to be no good.

Now that bombing has started in real earnest a great many people are having to do something about glass in wartime: the lucky ones are wondering what is the best thing to do or whether their existing schemes are good enough; the others are discussing with their architects what schemes of repair or replacement will be the best and cost them the least money in the long run.

The aim of this issue is to help solve these problems. It does not and cannot give cast-iron, concise rulings about the efficiency of particular protective methods in particular circumstances—no one can do that. What it does do is to show the average comparative efficiency of various protective methods, give references to authoritative sources of information about glass under blast and the best protective devices, and suggest to architects how best to set about protecting the glass of various building types against the most serious consequences of breakage.

It tries, in short, to state the true facts about glass in wartime and to prove that if the situation is not as good as one could wish, it is not as bad as many think.



The age of glass: a scheme illustrating the extent to which glass was being used in internal decoration when war broke out.

1. THE DANGERS

Glass splinters which have been prevented from flying by fabric netting. The pane was left hanging in one piece.

WHAT is chiefly feared about glass in air raids is the physical danger of flying glass splinters. This is a very real danger, though it tends to be a little exaggerated by two points being overlooked: first, glass more often falls outwards than flies into a room; second, plate glass, though it can inflict much worse wounds than lighter types, does not fly so far.

•

The other dangers of glass in air raids are consequent upon its breaking. They include damage from weather action, loss from theft, glass dust and small splinters in food and stock, and so on.

•

People want to prevent both the dangers at least cost. And as architects are well aware, the first questions they ask are what method will guarantee complete protection to their particular building and how much will it cost. When they are told that no method can guarantee complete protection they ask which method will give the best results for a given expenditure. And this question can be answered with approximate accuracy in terms of the average relative efficiency of different glasses and of the same glass protected in different ways.

•

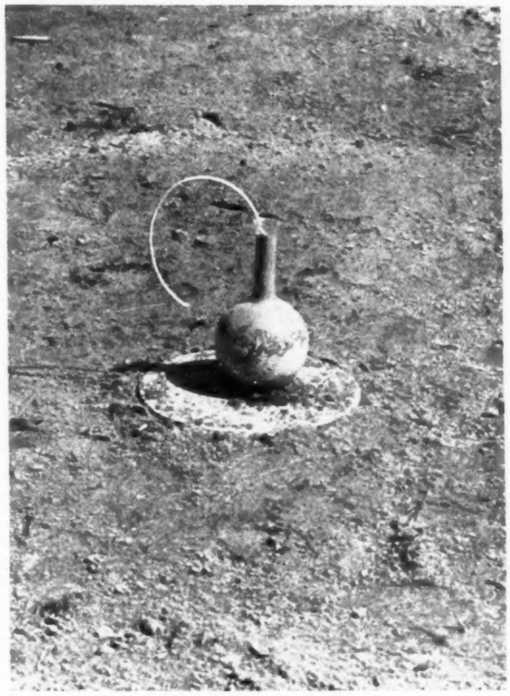
This relative efficiency has been established by official tests carried out by the Research and Experiments Branch of the Ministry of Home Security. These tests have been supplemented by the privately arranged tests which are described on the following pages, and from official recommendations based on the results of the official tests it would appear that there is no important discrepancy between the official results and those obtained from the private tests.

•

In these private tests, different types of glazing and protection were subjected to series of tests under identical conditions and their results establish the relative efficiency of different types of glass and glass protection with considerable accuracy.

2. THE TESTS

AS the execution of a large series of tests with actual aerial bombs would not only have been inordinately costly but also impossible in practice for a private organization, the tests were carried out by using smaller blast charges at much decreased distances. The bombs used were round-bottomed flasks each containing 2 lb. of blasting powder. The effect of such a bomb at any particular distance was considered to be approximately the same as would be produced by a 500-lb. H.E. bomb at twelve times the distance. This must be regarded as only generally true, since the effect of a bomb depends on the form of the blast wave as well as on the weight of the explosive it contains. Results based on the above assumption can, however, be considered as reasonably accurate.



Standard

500-lb. H.E. bomb exploding at distance of	yds. 200/250	yds. 160/200	yds. 120/150	yds. 80/100	yds. 40/50

Equivalent

2 lb. of blasting powder in glass flask tamped, exploded at distance of	ft. 50	ft. 40	ft. 30	ft. 20	ft. 10

TEST NO. 1

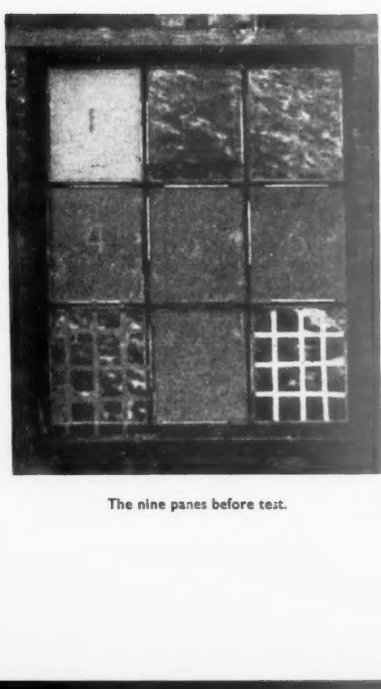
UNPROTECTED COMMON GLASS

★ *The following table gives the results of tests on common types of glass when unprotected. It will be noticed that these glasses include most of the window glass used in this country except 18 oz. glass—which is still used extensively in cheap houses, and indeed in houses which are not so cheap. But it may be taken for granted, after an examination of the test results, that glass of this weight would yield more easily than heavier types.*

TYPE OF GLASS AND SIZE OF PANE	Explosion at 50 ft. equivalent to a 500-lb. H.E. bomb at 200-250 yards	Explosion at 40 ft. equivalent to a 500-lb. H.E. bomb at 160-200 yards	Explosion at 30 ft. equivalent to a 500-lb. H.E. bomb at 120-150 yards	Explosion at 20 ft. equivalent to a 500-lb. H.E. bomb at 80-100 yards	Explosion at 10 ft. equivalent to a 500-lb. H.E. bomb at 40-50 yards	REMARKS
24 oz. Sheet Glass 15" × 15"	Completely shattered	—	—	—	—	Fragments dislodged and projected towards explosion.
32 oz. Sheet Glass 22" × 18"	Undamaged	Undamaged	Undamaged	Undamaged	Glass shattered	Fragments dislodged and projected towards explosion.
¼" Rough Cast Double Rolled 15" × 15"	do.	do.	do.	do.	do.	Some fragments dislodged.
¼" Polished Plate Glass 84" × 84"	do.	do.	Glass shattered	—	—	Fairly large fragments. They were only projected a few feet and fell both in front and in rear of window opening.
¼" Polished Plate Glass 84" × 84"	do.	do.	Undamaged	Undamaged	Completely shattered	Some fragments were projected 12 feet in front and others to a distance of 6 feet behind window opening.

TEST NO. 2: TESTS OF COMMON

Pane No.	Type of Glass	TEST 1 Explosion at 50 ft. equivalent to a 500-lb. H.E. bomb at 250 yards	TEST 2 Explosion at 40 ft. equivalent to a 500-lb. H.E. bomb at 200 yards	TEST 3 Explosion at 30 ft. equivalent to a 500-lb. H.E. bomb at 150 yards	TEST 4 Explosion at 20 ft. equivalent to a 500-lb. H.E. bomb at 100 yards	TEST 5 Explosion at $10\frac{1}{2}$ ft. equivalent to a 500-lb. H.E. bomb at 50 yards
		NINE PANES EACH 22″ × 18″★				
1	24-oz. Sheet, millboard behind.	Major portion of glass shattered and fell outwards, millboard held.	Millboard blown in and left hanging by bottom edge. Further glass fragments dislodged.	—	—	—
2	32-oz. Sheet ..	Undamaged	Undamaged	Undamaged	Undamaged	Glass shattered and fell outwards. A few pieces only held in bottom of frame.
3	24-oz. Sheet with transparent cellulose tape.	Glass broken but portion held together by strips.	Further fragments of glass dislodged, strips still holding.	Further fragments of glass dislodged, strips still holding.	Strips and remainder of glass blown out.	—
7	24-oz. Sheet with staggered paper strips on both sides.	Completely shattered. Glass projected 3 ft. outwards from wall.	—	—	—	—
9	24-oz. Sheet with surgical tape on back.	Completely shattered. Tape still held glass fragments but was projected 3 ft. outwards from wall.	—	—	—	—
		SIXTEEN PANES EACH 15″ × 15″★				
10	24-oz. Sheet ..	Completely shattered.	—	—	—	—
11	24-oz. Sheet with paper strips on back.	Undamaged ..	Undamaged ..	Completely shattered. Strips held major portion of broken glass together.	—	—
12	24-oz. Sheet with paper strips on both sides.	Undamaged ..	Undamaged ..	Completely shattered.	—	—
13	24-oz. Sheet with wire netting behind.	Glass completely shattered.	—	—	—	—



The nine panes before test.

After the first test: All panes damaged save those with wired glass and one with 32-oz. sheet. Millboard held behind pane I.

★*The panes for which test results are not given on these two pages were glazed with wired or toughened glass. Results of tests on these panes are given on page 476.*

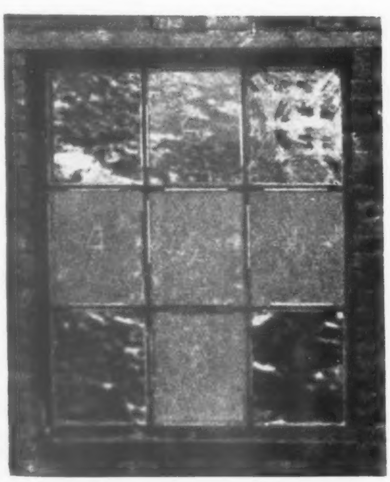
Key to types of glass and protection, reading from left to right from top downwards: 24-oz. sheet, millboard behind; 32-oz. sheet; 24-oz. sheet with transparent cellulose tape behind; $\frac{1}{4}$-in. wired glass, $\frac{7}{8}$-in. hexagonal mesh; $\frac{1}{4}$-in. wired glass, $\frac{3}{8}$-in. mesh; $\frac{1}{4}$-in. wired glass, $\frac{1}{2}$-in. mesh; 24-oz. sheet with staggered paper strips both sides; double-glazed, 24-oz. sheet behind, $\frac{1}{4}$-in. Georgian wired glass in front; 24-oz. sheet with surgical tape behind.

GLASSES, VARIOUSLY PROTECTED

Pane No.	Type of Glass	TEST 1 Explosion at 50 ft. equivalent to a 500-lb. H.E. bomb at 250 yards	TEST 2 Explosion at 40 ft. equivalent to a 500-lb. H.E. bomb at 200 yards	TEST 3 Explosion at 30 ft. equivalent to a 500-lb. H.E. bomb at 150 yards	TEST 4 Explosion at 20 ft. equivalent to a 500-lb. H.E. bomb at 100 yards	TEST 5 Explosion at 10 ft. equivalent to a 500-lb. H.E. bomb at 50 yards
14	24-oz. Sheet with strips of surgical tape on back.	Undamaged ..	Undamaged ..	Glass broken but major portion held by strips.	As for 30 ft. but a few small portions of broken glass dislodged.	Total collapse, except for a lateral section of strip which still held to frame.
17	24-oz. Sheet with strips of insulating tape on both sides.	Completely shattered.	—	—	—	—
18	24-oz. Sheet with transparent cellulose tape on back.	Undamaged ..	Undamaged ..	Completely shattered, strips left hanging from bottom of frame.	—	—
21	24-oz. Sheet with perforated brown paper on back.	Undamaged ..	Undamaged ..	Glass shattered, paper dislodged but holding.	Paper completely dislodged.	—
22	24-oz. Sheet with staggered paper strip gummed on both sides of glass.	Glass and strips shattered. One strip left hanging and supporting small fragments of glass.	Remains completely dislodged.	—	—	—
23	24-oz. Sheet with millboard behind.	Glass shattered; millboard dislodged and bulging outwards but holding.	Millboard completely dislodged.	—	—	—
24	24-oz. Sheet with plywood shutter tacked behind and touching glass.	Undamaged ..	Glass shattered, board still holding in position.	Board still holding.	Board dislodged	—

TWO PANES EACH 24″ × 24″

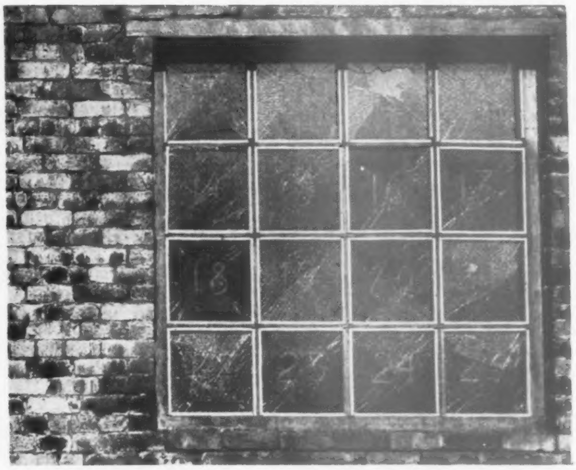
TYPE OF GLASS	Explosion at 70 ft. equivalent to 500-lb. H.E. bomb at 450 yards	Explosion at 60 ft. equivalent to 500-lb. H.E. bomb at 350 yards	Explosion at 50 ft. equivalent to 500-lb. H.F. bomb at 250 yards
18-oz. sheet coated inside with textile netting.	One pane broken, most of glass remained stuck to netting.	Other pane broken, portion of glass came out.	Completely shattered both panes and nearly all fell outwards, but net still in position in one opening.



After third test. Further fragments dislodged. Millboard behind pane I blown out by second test. Wired glass and 32-oz. plain sheet unharmed.

After second test (2-lb. bomb at 20 ft.) of ½-in. plate glass window protected on back with netting firmly glued to glass. A typical example of the "diaphragm" fracture which occurs when blast hits glass at right angles. After first test, glass bulged forward 2 to 3 ins. After this second test, glass came to rest with backward bulge of 3 to 4 ins. at centre.

TEST NO. 3: WIRED AND TOUGHENED GLASS



A frame of 15 panes of wired glass and one of ¼-in. rough cast, double rolled, after the final test at distance of 10 ft. approximately equivalent to 500-lb. bomb at 50 yds. All the wired glasses, though badly cracked, have held. The rough cast pane had fragments dislodged.

★ *The results of tests on various types of wired glass and on leaded and copperlite glasses and armourplate are grouped together because they are "special" glasses in the sense of being less commonly used. But it should not be assumed that they were tested separately. The tests on all types of wired glass and armourplate took place at the same time with the same explosion and in adjoining frames to those recorded on previous pages. The tests on leaded and copper glasses (page 478) took place at the same place and with exactly the same charge but not at the same time.*

Type of Glass and Size of Pane	Explosion at 70 ft. equivalent to a 500-lb. H.E. bomb at 280-350 yards	Explosion at 60 ft. equivalent to a 500-lb. H.E. bomb at 240-300 yards	Explosion at 50 ft. equivalent to a 500-lb. H.E. bomb at 200-250 yards	Explosion at 40 ft. equivalent to a 500-lb. H.E. bomb at 160-200 yards	Explosion at 30 ft. equivalent to a 500-lb. H.E. bomb at 120-150 yards	Remarks
Wired Glass, 13 panes, 22″ × 18″	Undamaged	Undamaged	Undamaged	3 panes cracked.	Remaining 10 panes cracked.	Although cracked the wire reinforcement held the pieces together as a complete panel which remained rigid in the frame.
Wired Glass, 19 panes, 15″ × 15″	do.	do.	do.	5 panes cracked.	Remaining 14 panes cracked.	
Wired Glass, 84″ × 24″	Cracked	No change	No change	No change	Cracked considerably	The panel was badly buckled by the blast: it had forced the lead cover strips and slid down the glazing bars mainly in large pieces.
¼″ "Armourplate" 15″ × 15″	Undamaged	Undamaged	Undamaged	Undamaged	Undamaged	No damage at all.

PANES EACH 15″ × 15″

Type of Glass	TEST 1 Explosion at 50 ft. equivalent to a 500-lb. H.E. bomb at 250 yards	TEST 2 Explosion at 40 ft. equivalent to a 500-lb. H.E. bomb at 200 yards	TEST 3 Explosion at 30 ft. equivalent to a 500-lb. H.E. bomb at 150 yards	TEST 4 Explosion at 20 ft. equivalent to a 500-lb. H.E. bomb at 100 yards	TEST 5 Explosion at 10 ft. equivalent to a 500-lb. H.E. bomb at 50 yards
¼″ Wired Glass (⅞″ hexagonal mesh).	Undamaged	Undamaged	Undamaged	Undamaged	Several cracks radiating from a central point, glass bulging outwards slightly
¼″ Wired Glass (⅜″ mesh) ..	Undamaged	Undamaged	Undamaged	Four main cracks appeared radiating from approximately a central point.	Further subsidiary cracks. Glass bulging outwards slightly.
¼″ Wired Glass (½″ mesh) ..	Undamaged	Undamaged	Undamaged	Undamaged	Several cracks resulted, radiating from a central point and running towards the corners.
¼″ Wired Glass (½″ mesh) ..	Undamaged	Undamaged	Undamaged	Single diagonal crack in glass.	Additional cracks developed, radiating from two central points, glass rigidly held in frame.
¼″ Clear "Armourplate" ..	Undamaged	Undamaged	Undamaged	Undamaged	Undamaged
¼″ Wired Glass (⅞″ hexagonal mesh).	Undamaged	Undamaged	Undamaged	Undamaged	Undamaged
¼″ Georgian Wired Cast ..	Undamaged	Undamaged	Undamaged	Undamaged	Several cracks radiating from an upper central position.

TEST NO. 4: UNFRAMED AND FRAMED PLATE

First Test :

WINDOWS 7 ft. square of 6·9 mm. polished plate were fitted in ordinary wood frames in two openings. Glass in second opening was supported on each side by a wooden grille of 3¼ in. by 1¾ in. timbers seating on to glass by ½ in. felt strip. Grille divided glass into twelve openings each measuring about 3 ft. 4 in. by 2 ft. 1 in. 2-lb. bombs were exploded at right angles to wall, mid-way between the two openings at distances of 50, 40 and 30 ft.

Results :

First and second explosions : No damage. Third explosion : Both windows shattered. Pieces from unsupported window fell 18 ft. in front and 6 ft. behind. This window broke in "diaphragm" manner.

The braced glass broke as though each of the six clear rectangular portions had behaved to some extent, though not entirely, as separate pieces of glass, in the sense that there was a semblance of the "diaphragm" type of fracture in each of the six sections. The fragments were not thrown so far forward of the wall, the maximum distance being only 8 ft. as against 12 ft. for the unsupported window. Fragments were projected behind the wall to the same distance as behind the unsupported window, namely, 6 ft.

Second Test :

Windows arranged as for previous test, but in this case no packing material was placed between frame and glass, and timbers were fitted over grille to ensure that contact was made between grille and glass at centre as well as at edges. 2-lb. bombs were exploded at 30 and 20 ft. in position as before.

Results :

First explosion : The braced window was broken, but the glass was dislodged from only two sections. Each of these two sections showed fractures approximating closely to the "diaphragm" type of burst, as though they had broken almost as single panes of glass ; the glass in the other sections simply showed cracks radiating from the two sections which had burst.

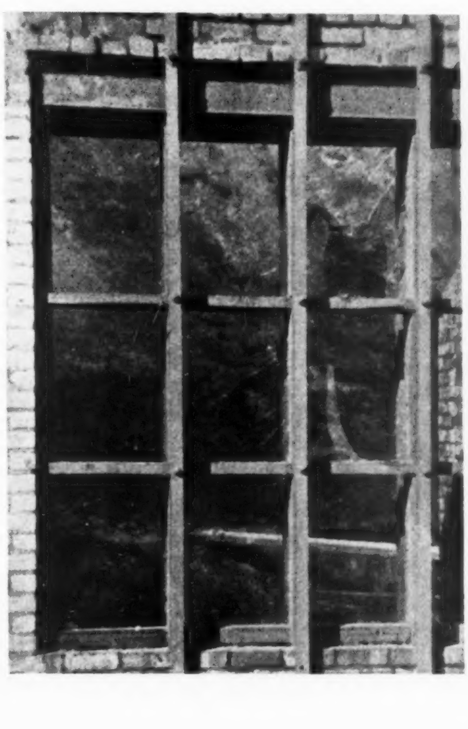
Second explosion : The glass burst in all the remaining ten sections, each section behaving as though it had been a separate piece of glass.

Conclusions

When a stiff grille is bedded direct on glass and braced to ensure contact throughout, considerable reinforcement is obtained, danger from falling glass is greatly reduced, and the grille could serve as structure to which weatherproof material could rapidly be fixed. On the other hand it would only be possible to fix such a heavy grille to shop windows in rare cases.

Above, the unframed and framed plate glass windows used in the first test described on this page, breaking after third explosion at 30 ft.

Below, the close-framed plate glass window used in the second series of tests, after the second explosion.



TEST NO. 5: COPPER AND LEAD GLAZING

Top, the lead and copper glazed panes used in the tests described on this page before the first explosion.

Above, after the fourth explosion at 20 ft. Small pieces of glass fell out from the cracked panes but the most marked effect was the pulling forward 3 in. of the top edge of the lower copperlight panel. Bottom, rear view of panels after fourth explosion, showing wood mouldings split away and bottom right hand edge of upper lead panel twisted inwards. (Bottom copperlight panel had been removed by hand before photograph was taken.)

THE tests were made with a 4 ft. square window opening glazed as follows :

Two panels of copper glazing :

One panel, 14 in. by $21\frac{1}{8}$ in. wide, made up in diamond-shaped panes, $6\frac{1}{4}$ in. by 4 in., of 32-oz. O.Q. clear sheet glass.

One panel, $28\frac{1}{8}$ in. high by $21\frac{1}{8}$ in. wide, made up in rectangles, $5\frac{1}{2}$ in. by 4 in., of 32-oz. O.Q. clear sheet glass.

Both panels built up with $\frac{1}{8}$ in. section copper dividing cames (overall dimensions ·125 in. by ·250 in.) and $\frac{3}{8}$ in. channel section frames (overall dimensions ·375 in. by ·250 in. by ·020 in. thick).

Heavy electro-copper deposited for a period of 24 hours giving a plating 1/64th of an inch thick of pure electrolytically deposited copper.

Finally, both panels brushed over both surfaces with a mixture of boiled oil, red lead and dryers to ensure watertightness.

Two panels of leaded glazing :

One panel, 14 in. high by $21\frac{1}{8}$ in. wide, made up in rectangles, $4\frac{1}{2}$ in. by $4\frac{1}{4}$ in., of 24-oz. O.Q. clear sheet glass, with $\frac{5}{16}$ in. lead cames (two vertical cames steel reinforced with bright flat M/S wire 8 by $17\frac{1}{2}$ g.).

One panel, $28\frac{1}{8}$ in. high by $21\frac{1}{8}$ in. wide, made up in diamond-shaped panes, $6\frac{3}{4}$ in. by 4 in., of 24-oz. O.Q. clear sheet glass, with $\frac{5}{16}$ in. lead cames (three diagonal cames steel reinforced with bright flat M/S wire 8 by $17\frac{1}{2}$ g.).

Both panels with $\frac{1}{2}$ in. flat section lead frames, cemented with standard quality leaded light cement.

The tests were made with 2-lb. bombs fired from positions on a line perpendicular to the window wall and 16 ft. to one side of the centre of the window opening, giving blasts which increased in obliquity as they became more intense.

RESULTS :

First explosion at 50 feet

No apparent change, though the diamond-leaded panel may have been slightly bulged inwards as a result of the blast.

Second explosion at 40 feet

No damage to the lead or copper cames nor to the glass, though both the diamond leaded and the square leaded panels appeared to have bulged slightly. The putty at the top of the large copperlight panel (rectangular panes) had been disturbed, and the sprigs holding the top edge had been bent forward, showing that the window had been pulled violently forward at the top during the suction part of the blast wave.

Third explosion at 30 feet

This further increased the bulging of the leaded light panels, though the total extent of bulging was still very slight. It also caused three panes of glass to crack, namely the pane in the top left corner of the rectangular leaded light, the pane in the top right corner of the rectangular copperlight panel, and the pane first from the bottom on the right side of this panel. The three panes were cracked along directions running approximately at 45° to the sides of the window, the cracks being typical of those which occur when glass is subjected to twisting ; twisting is to be expected on panes in or near corners when the windows are bulged by the blast.

Fourth explosion at 20 feet

This caused two additional panes in the rectangular leaded light to crack, and one additional pane in the rectangular copperlight panel. The form of the cracks again suggested twisting of the panes owing to a general bulging of the panels.

In addition to the cracks in the rectangular panes, three panes had cracked in the diamond leaded light and one in the diamond copperlight panel. These again were of the type produced by bulging the lights inwards.

The most marked effect produced by the blast, however, was that the top edge of the rectangular copperlight panel was pulled forward 3 in. from the frame, the panel being curved forward from the bottom edge, which was still held firmly by the putty and sprigs. The sprigs in the top of the frame and in the upper part of the side members had been bent, so that they stood out at right angles from the frame, as the panel had been drawn outwards during the suction part of the blast wave. In five places the joints between the copper cames in this panel had started, the separation at one joint being nearly $\frac{1}{8}$ in. The lower right-hand corner of the rectangular leaded light had also been drawn forward a little, displacing the putty locally, but there was no damage of any kind to the metal. Small pieces of glass had fallen from four of the broken panes, but the amount of glass dislodged was very small.

TEST NO. 6: REVOLVER TEST ON LENSES

★ *The test was carried out to find the approximate resistance of toughened glass lenses to small objects travelling with great velocity. But, though the tests were carried out to discover some indication of the resistance of toughened glass lenses to bomb splinters, it must be borne in mind that such splinters at close range have a velocity and penetrative power much exceeding that of a bullet.*

FIRST TEST :

A Colt ·45 revolver was fired at a single toughened glass lens set in 5 in. concrete.

Range :

10 yds. 1st shot : Bullet struck close to edge of lens. Lens fractured. $\frac{1}{2}$ in. dia. cone-shaped hole pierced. Side of lens dislodged.

10 yds. 1st shot : Lens fractured. $\frac{1}{2}$ in. dia. cone-shaped hole pierced. Bullet found at the front of slab.

10 yds. 1st shot : Surface of lens scored, bullet did not penetrate. No fracture. No reason can be offered for this result.

SECOND TEST :

Two toughened lenses were double glazed in 5 in. concrete slab, concave sides being fixed inwards and shots fired from same ·45 Colt revolver.

Range :

10 yds. 1st shot : Bullet struck close to edge of front lens. Front lens fractured, some fragments fell from the inner surface of the front lens but it was not pierced. Rear lens undamaged.

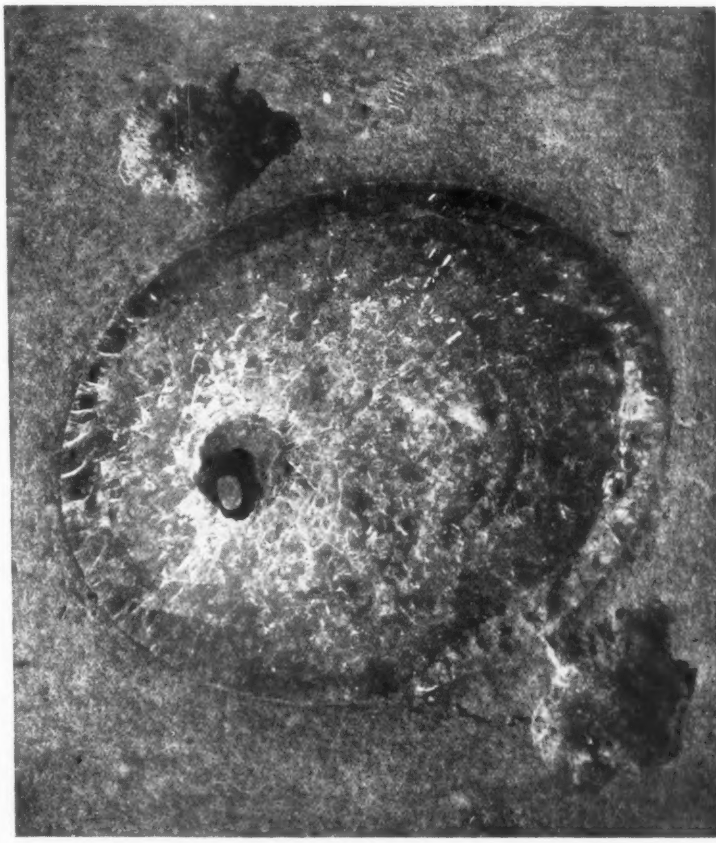
10 yds. 1st shot : Front lens fractured, 1 in. dia. cone-shaped hole pierced. Bullet observed between front and back lens. Back lens slight mark on surface where bullet had touched, otherwise undamaged.

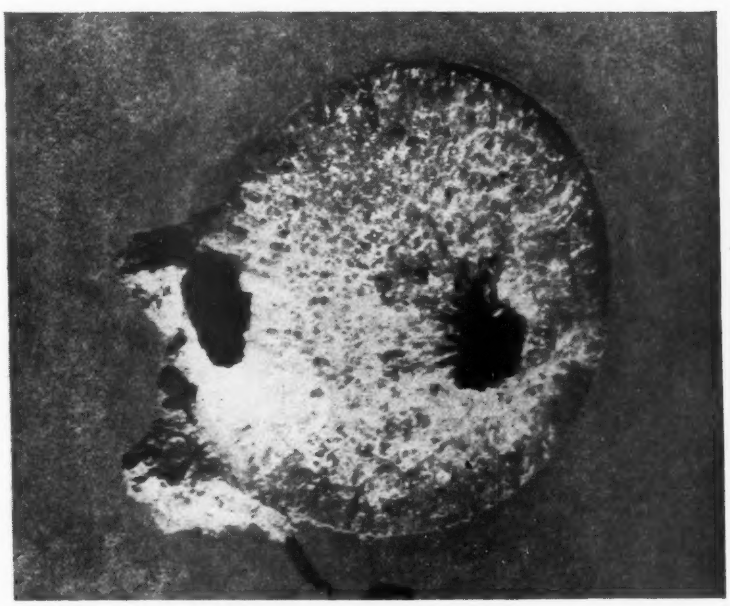
7 yds. 1st shot : Front lens fractured, 1 in. dia. cone-shaped hole pierced. Bullet observed between front and back lens. Back lens, slight mark on surface where bullet had touched, otherwise undamaged.

7 yds. 2nd shot : Bullet made a new hole in the edge of the front lens. Back lens undamaged.

5 yds. 1st shot : Front lens fractured, 1 in. dia. cone-shaped hole pierced. Bullet observed between front and back lens. Back lens, slight mark on surface where bullet had touched, otherwise undamaged.

5 yds. 2nd shot : Bullet hit rim of previous hole. Although it struck the first lens where it was very thin due to the fracture caused by the first shot, this lens offered some resistance as the back lens was undamaged. The back lens was marked by a splash of lead.

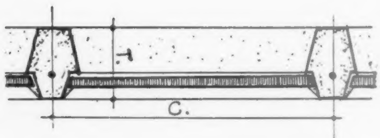




Two 7-in. diameter lenses double glazed in 5-in. concrete slab. Top: After first shot at 10 yards. Bullet pierced front lens, glass diced, rear lens undamaged, bullet in cavity. Above: Front view of lenses after two shots at 7 yards. Both bullets pierced front lens, glass diced, rear lens undamaged. Bullets and powdered glass in cavity.

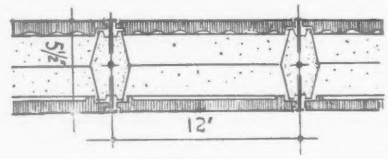
TEST NO. 7: GLASS CONCRETE CONSTRUCTION

★ *The tests of the window constructions described below were carried out in a similar manner to those described on previous pages save that the charge was hung from a gantry and not placed on the ground. The charge was also fired at close ranges since there was reason to suppose that 'strong' glass in small areas, rigidly held in reinforced concrete framing, would offer considerable resistance to blast.*



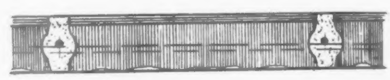
TYPE 1

Panel consisted of nine $10\frac{1}{8}$-in. square glass panels set in $2\frac{1}{4}$-in. by $1\frac{1}{2}$-in. reinforced concrete ribs. Six panels, left and right, were glazed with two types of wired glass units. Centre three panels were glazed with Armourplate.



TYPE 2

Construction consists of R.C. grid, about 3 in. by $1\frac{1}{2}$ in. in section and 12-in. centre to centre, glazed back and front with glass units. On left, three wired units back and front; centre, three pressed units back and front; right, three pressed units at front and three Armourplate units behind.

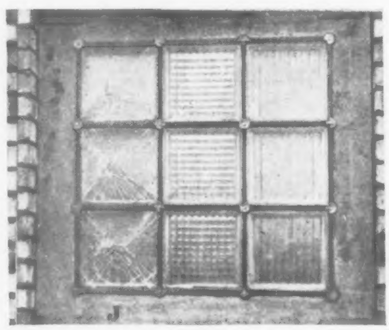


TYPE 3

Glass brick construction consisting of 8 in. by 8 in. by $1\frac{1}{2}$ in. glass bricks, plain one face, Flemish pattern externally, fixed in $1\frac{3}{4}$ in. by $1\frac{1}{4}$ in. R.C. framing. On rear face of lenses $\frac{1}{4}$-in. Armourplate is fixed by special process.

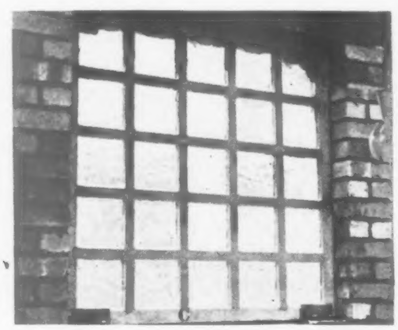
Test 1. Explosion equal to 500 lb. bomb at 40 yds.:

Wired glass units, left and right, cracked. Armourplate units undamaged. Slight brickwork displacement.



Test 1. Explosion equal to 500 lb. bomb at 40 yds.:

Wired units cracked outwards radially: no glass fell. Slight shelling of outer pressed lenses. Rear panels undamaged.



Test 1. Blast equal to 500-lb. bomb at 14 yds.:

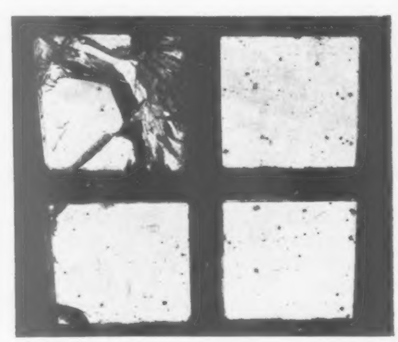
Pitting of front surface by glass splinters from bomb flask. No other damage. The blast forced back steel joists to which panel was clamped: bottom joist 1 in., top joist 2 in.

Test 2. Explosion equal to 500-lb. bomb at 24 yds.:

Wired units, Type 1, blown in for distance of 6 ft. Wired units, Type 2, broken but largely hanging. Armourplate units undamaged. Frame slightly cracked at six points.

Test 2. Explosion equal to 500-lb. bomb at 24 yds.:

Wired glass outer units, left, sucked out and fragments fell. Rear wired units cracked. Five pressed units at front broken and two at back cracked. Armourplate units undamaged.



Test 2. Blast equal to 500-lb. bomb at 12 yds.:

Panel completely dislodged, several glass lenses being broken by impact or falling debris. No glass was dislodged from back face. (Above detail of typical cracked lens.)

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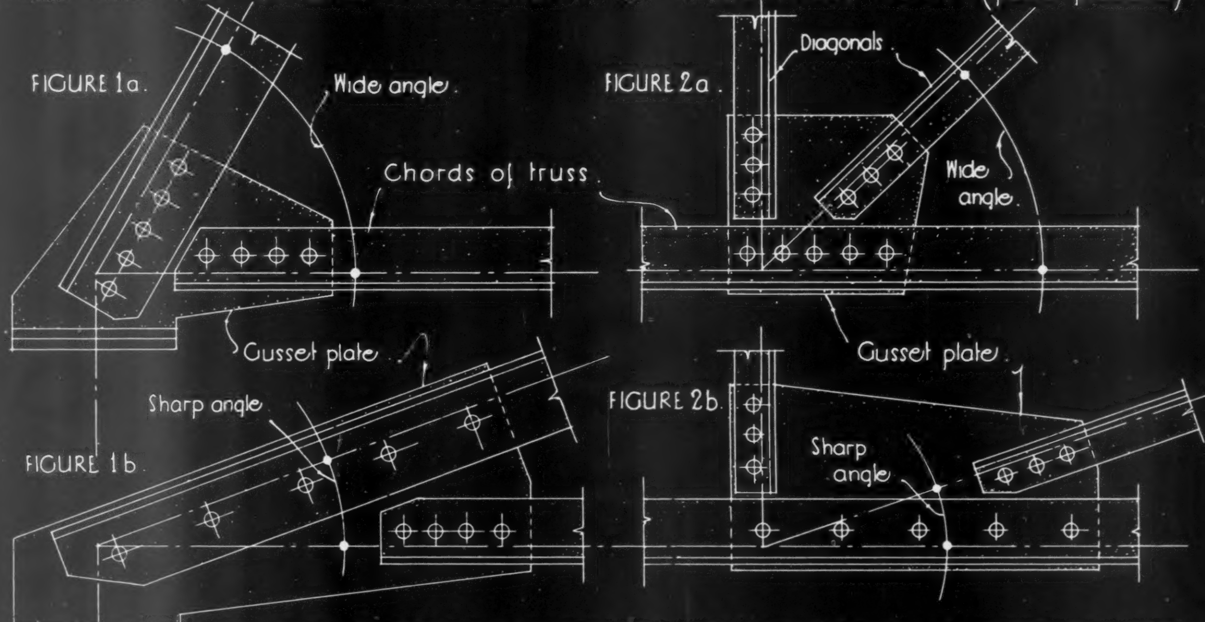
SYSTEMS AND ECONOMICAL ARRANGEMENTS OF STEEL TRUSS NODES (special problems):



ECONOMY IN GUSSET PLATES RESULTING FROM WIDE ANGLES BETWEEN ADJACENT TRUSS MEMBERS.

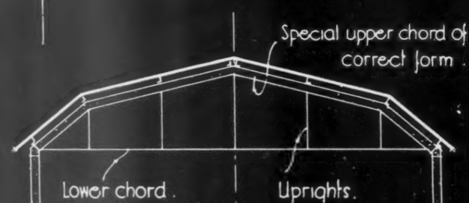


FIGURE 3: ECONOMY IN NODES BY OMISSION OF ALL DIAGONALS.

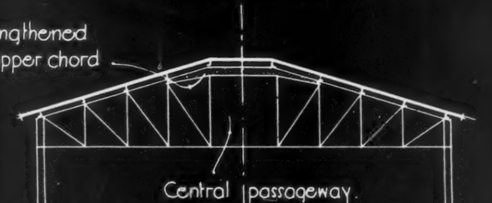


FIGURE 4: ECONOMY BY OMISSION OF CENTRAL MEMBERS.

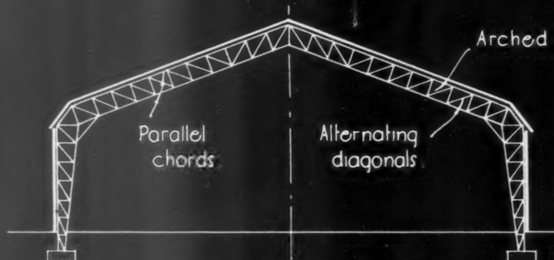


FIGURE 7. FRAMED LATTICED CONSTRUCTION

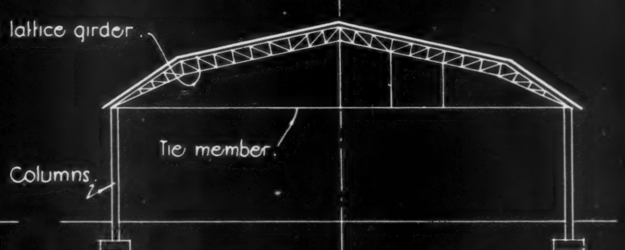


FIGURE 6: ARRANGEMENT FOR INCREASED HEADROOM AT SUPPORTS.

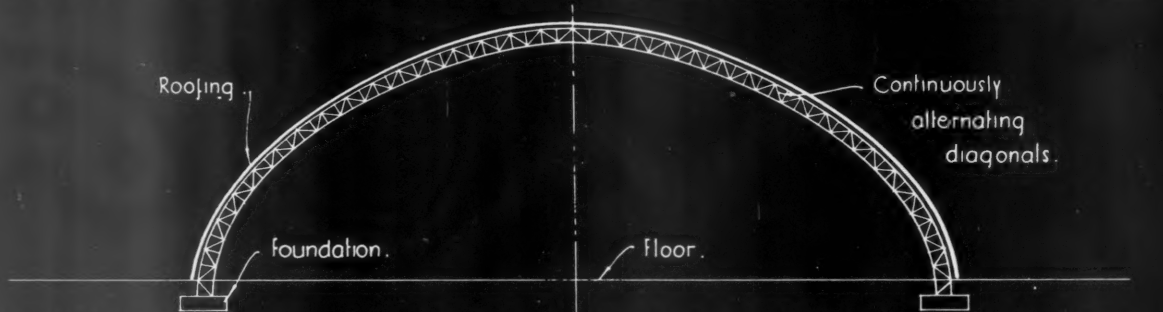


FIGURE 5: ARRANGEMENT OF ARCHED LATTICE CONSTRUCTION FOR WIDE SPANS.

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INFORMATION SHEET: STEEL FRAME CONSTRUCTION: Nº 39.

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STRUCTURAL STEELWORK

Subject Steelwork for Roof Construction, 7: Systems and Economical Arrangements of Steel Truss Nodes

General:

This series of Sheets on steel construction is not intended to cover the whole field of engineering design in steel, but to deal with those general principles governing economical design which affect or are affected by the general planning of a building. It also deals with a number of details of steel construction which have an important effect upon the design of the steelwork.

Both principles and details are considered in relation to the surrounding masonry or concrete construction, and are intended to serve in the preliminary design of the building so that a maximum economy may be obtained in the design of the steel framing.

This Sheet is the thirty-ninth of the series, and illustrates the usual systems and economical arrangement of the nodes in steel roof trusses.

Size of Gussets:

An important consideration in the design of a truss is that the gusset plates arranged to connect different members should not be too large. Large gusset plates are costly in material as well as in labour, as the number of rivets is usually proportional to the size.

Angle of Truss Members:

As a general rule it can be stated that two members meeting at a sharp angle require a larger gusset plate than if the angle is nearer 90 degrees. For this reason, too sharp an angle between the chords intersecting at a support should be avoided, and Figures 1*a* and *b* illustrate this problem clearly. Similarly, steep diagonals are preferable to flat ones, and this is illustrated in Figures 2*a* and *b*. Only if the number of nodes can be reduced by such method is it worth while arranging flat diagonals.

Omission of Diagonals:

By making one chord rigid enough to take certain bending moments, it is often possible to omit diagonals altogether, and thereby reduce the size of the gussets to a minimum. This arrangement is economical only if the chord is formed in such a way that bending moments are small.

For instance, with a form as shown in Figure 2 on Sheet No. 37 of this series, a truss can be constructed as shown here in Figure 3, the upper chord consisting of two channels, and with only slight bending moments, particularly if a heavy one-sided load has not to be taken into consideration.

Another example illustrating the stiffness of the upper chord being utilised for economy, is that in which an opening for a passageway is to be left in the centre of a truss. See Figure 4. If the load is symmetrical, no diagonals are required in the centre panel; but if a one-sided load does occur the shear force in the centre is comparatively small, and bending moments can then be taken by a rigid upper chord.

Latticed Arches:

Lattice construction, by means of which the size of the gusset plates may be reduced to a minimum, can be used for arches. These arches may span between two foundations, as in Figure 5, or they may rest on columns and be restrained by a tie member, as in Figure 6. The construction in Figure 5, which is commonly used for market halls, railway stations, exhibition halls, etc., has the advantage that wind forces also can be transmitted to the foundation. On the other hand, due to the slope of the arch, the headroom is rather small near the supports, and where this is of importance the arrangement in Figure 6 should be given preference. Wind forces, of course, would have to be taken either by wind bracing in the roof, or by columns rigidly fixed to the foundations. Both in Figures 5 and 6 the chords of the truss are almost parallel to each other, and the simplest arrangement is that of continuously alternating diagonals.

An arrangement similar to the arch in Figure 5, but more like a frame, is shown in Figure 7. Filling members are arranged in very much the same way, but as the bending moments are larger the depth of the frame is increased.

Previous Sheets:

Previous Sheets of this series on structural steelwork are Nos. 729, 733, 736, 737, 741, 745, 751, 755, 759, 763, 765, 769, 770, 772, 773, 774, 775, 776, 777, 780, 783, 785, 789, 790, 793, 796, 798, 799, 800, 801, 802, 804, 805, 806, 807, 808, 809 and 810.

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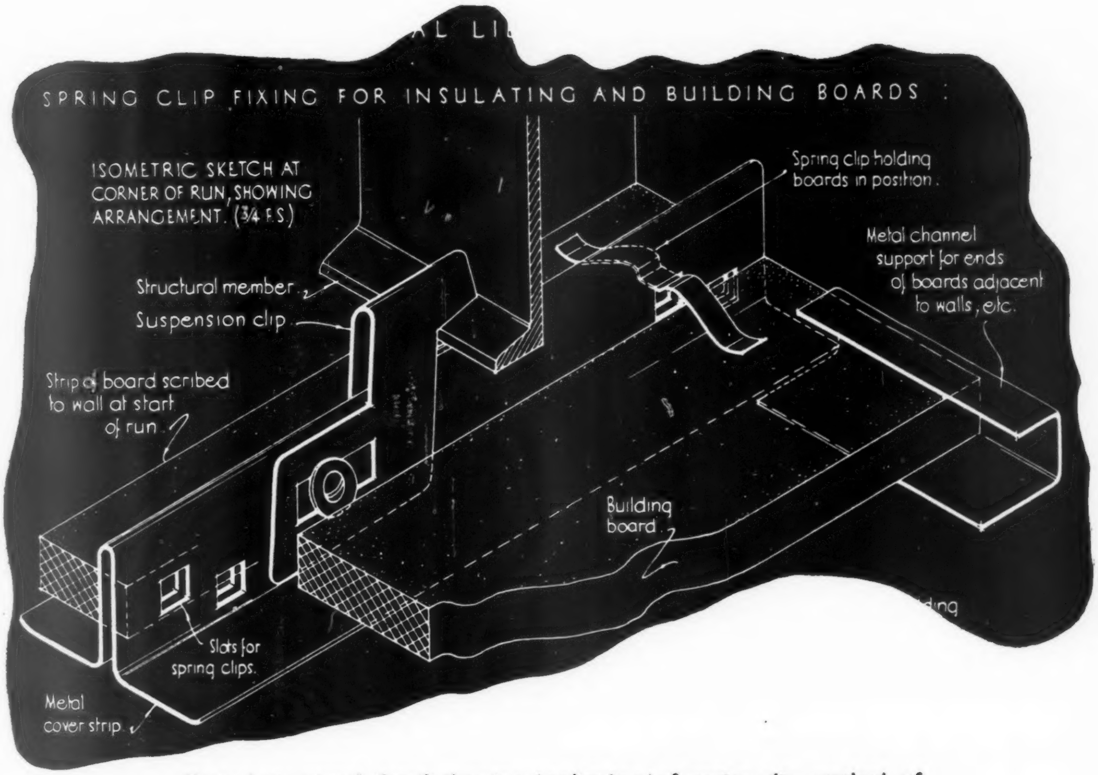
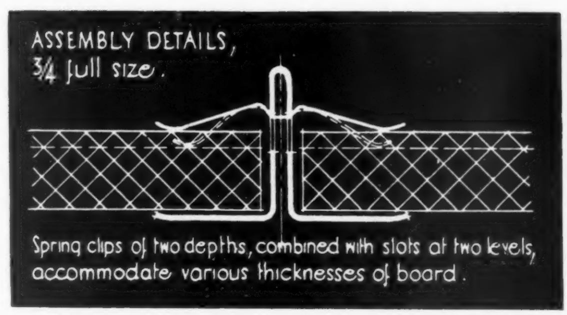
SPRING CLIP WALLBOARD FIXING



Typical structural detail showing application of spring clip method of suspending a building board ceiling beneath a light steel roof structure.

(For further details of construction, see Information Sheet 792 in THE ARCHITECTS' JOURNAL for May 23, 1940).



Cross-section through metal cover strip at junction of two-ceiling panels indicating how various thicknesses of board may be secured.

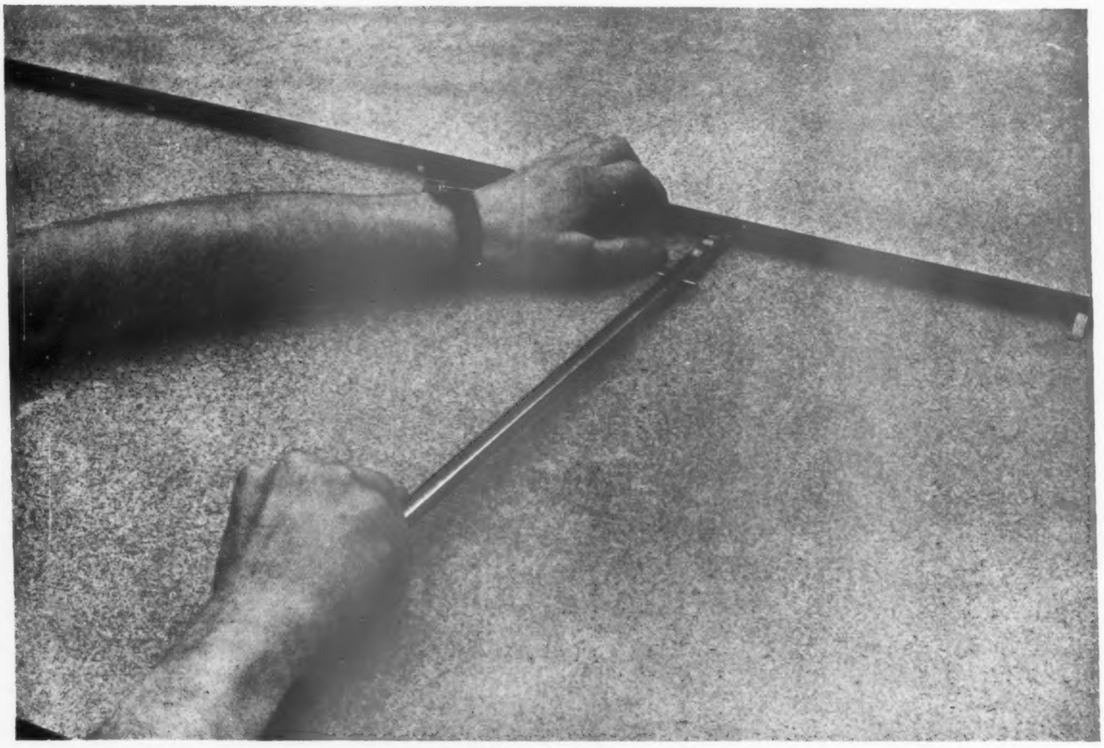
Emergency Hospital for H.M.O.W.

General view of a ceiling constructed of Tentest panels secured to slotted metal cover strips by the spring clip method.

Architects	- -	Messrs. Mitchell & Bridgwater.
Builders	-	Messrs. A. E. Symes, Ltd.

SPRING CLIP WALLBOARD FIXING

Close-up photograph of special tool for insertion of spring clips through the slots in the back of metal cover strips.



Inserting the spring clips in the slotted metal cover strips.

See further details on previous page.

3. LESSONS OF THE TESTS

THE main lessons of these tests and of the other evidence which has become so plentifully available since September 7 seem to be the following :

1. No glass can be guaranteed to remain unbroken if a 500-lb. H.E. bomb explodes within 50 yards of it. Much glass will be broken at greater distances, but a small proportion may survive at closer range.

2. No protective device of any kind (other than walling up the opening) will increase the resistance of any glass against breakage.

3. The likelihood of consequential damage after the glass has broken (physical injury, damage by weather and fire, loss by theft, etc.) can be reduced by the use of certain protective methods and can be much more reduced by the use of wired or other special types of glass.

4. Glass of heavier weight resists blast better than light-weight glass if firmly fixed. But being of heavier weight it requires stronger protection to hold its pieces in position after fragmentation. Pieces of heavy-weight glass do not travel far after fragmentation.

5. Glass in small sizes resists blast better than large panes of similar substance providing it is well fixed.

6. Glass lenses or other strong glass in small areas offer great resistance to blast when rigidly fixed in reinforced concrete frames.

7. All building owners should consider the possible consequences of damage to the glass of their own premises and take all reasonable steps to reduce them.

THE APPLICATION OF THE LESSONS

It is clear that the proper application of these lessons to any particular building calls for the consideration of a large number of factors. And it is equally clear that plumping, after a few casual inquiries, for a particular method, or—as happens in the great majority of cases—merely telling the manager to do the best he can with £50 will usually be a sheer waste of money.

For all large buildings the framing of the best protective scheme will require the manager and his architect to consider at least the following factors : the position of the building, the work carried on within it, its construction and form and the construction of its parts, the number of its staff and customers, the publicity attaching to it, the nature of stock, machinery and work carried on and the spaces occupied at times of "Alert" and "Imminent Danger."

It is therefore clear that no general rules can be laid down, but in general three principles are valid :

(1) The best all-round scheme for larger buildings usually results from a combination of "protection" and "substitution" according to the position of the glass in the building.

(2) Where large and costly glass areas are concerned, particularly those at street level, it is worth considering their removal and the substitution of smaller areas either of "protected" cheap glass or of more highly resistant glass.

(3) "Protected" glass or glass substitutes usually diminish light and visibility, look unsightly, and always cost money immediately with the prospect of costing more at the end of the war. A more highly resistant glass has neither of the first two drawbacks and may never have to be removed, though it may cost more to start with.

On the following pages the problems of glass protection for representative building types are considered in the light of average conditions and requirements.

Glazed partition wrecked by bomb which exploded inside a large store.

4. THE LESSONS APPLIED

1. THE HOUSE

ONLY simple schemes of glass protection stand much chance of being carried out in houses. This is so not so much because of the expense of better schemes as because all protective schemes are apt to be a nuisance—a nuisance to execute and a nuisance to maintain. And one of the chief lessons of the Blitz is the amount of danger normal people will run rather than subject themselves to petty inconvenience.

The householder in a dangerous area should, however, try to decide whether his household are going to be in their protected room or shelter on nine out of ten occasions when aircraft are nearby, or whether they are going to carry on until there are alarming noises in the immediate neighbourhood. In the first case it will only be necessary to have glass substitutes ready for windows if they are broken; in the second case all frequently-used rooms will need protection against flying glass as well.

One may assume that nearly all families will end, if they do not begin, by taking chances. In this case (save for those houses which have lead glazing and thus do not need additional splinter protection) the best method of protection would seem to be ½ in. wire mesh on detachable frames for all main rooms.

But this method only gives protection against flying glass: it gives no protection against wind and weather.

Other methods while not in general giving such good protection against flying glass do give a substantial measure of protection against weather when glass is cracked but not dislodged.

Such methods fall in four main groups:

(1) *Textile nettings:*

Any strong textile netting gives good protection if firmly stuck to glass and carried round glazing bars onto wood or metal frames. Such nettings are most easily applied in horizontal strips.

Some proprietary forms of netting only require to be moistened before being pressed on the glass, but it is probable that a better job is obtained if plain netting is used with a strong gum.

It should be borne in mind that condensation, or weather if the window is opened, may diminish adhesion and a final coat of varnish prevents this. All nettings diminish light and tend to pick up dust.

(2) *Cellulose and cellulose acetate films:*

These materials can be applied either in sheets or strips and diminish light very little. Sheets are preferable. Cellulose sheets and strips can be obtained ready gummed, but otherwise suppliers' advice should be followed concerning the adhesive that should be used for both cellulose and cellulose acetate sheets and strips.

It should be noted that cellulose film is harmed by moisture and a final coat of clear varnish should be applied over all treatments. Such a coat is not so necessary with cellulose acetate film but is still advisable.

Cellulose acetate films are available reinforced with both textile netting and fine wire, and are preferable to plain netting in that they do not pick up dirt to the same extent.

(3) *Strip treatments:*

These are not so good as those which cover the whole area of the glass. Strip protective treatments can consist of the transparent cellulose films, textile, cloth or adhesive tape. The closer the strips to each other the better the protection. The strips should be carried round glazing bars and onto frames.

(4) *Liquid coatings:*

Many liquid coatings are available as protective treatments for glass. These are usually made from rubber latex or synthetic resins.

In general, these coatings cannot be considered as satisfactory as other methods of protection. Their efficiency depends, first,

Windows in the Temple broken by bomb which burst in an adjoining upper storey.

upon their being applied thickly enough to bear the weight of cracked glass, and, second, upon continued pliability. It is difficult for either manufacturer or buyer to see that the first of these conditions is fulfilled, and most of the coatings tend to become brittle after a few months. The latter is a serious drawback as few owners will bother about renewal.

The Research and Experiments Branch of the Ministry of Home Security has so far approved two proprietary brands of such protective liquids.

Protective methods for house windows are more fully described in *Your Home as an Air Raid Shelter* but it may be said that only the simplest methods are worth recommending. House-owners, whether rich or poor, will usually not be bothered to carry out any other method.

2. OFFICES

THE position as regards offices and office buildings is very different. Managers and building owners have a much greater feeling of responsibility and the problems are more complex.

The protection of windows against blast in such buildings falls into two main divisions—protection against near bombs and protection against more likely distant explosions.

Since it is neither possible nor desirable to protect all windows against violent blast, it has to be assumed that when bombs fall nearby the inhabitants of the building will be in the shelter or refuge room where windows are either blocked up, non-existent or consist of small areas of toughened glass. Yet it is clear that in practice this may not occur, especially since many offices continue to work on during alerts: and therefore the "roof spotting" system carries with it the need for all glass being protected against flying as well as possible, and, in order to prevent weather damage and consequent dislocation of business, it is desirable that glass in external walls and roofs should continue to be weatherproof when broken.

The problem therefore falls into four main divisions.

1. *Protection of glass in external walls at ground level:* Heavy plate glass can be boarded up or removed and smaller areas of cheap protected glass or wired glass substituted. At the least it should be protected with wire mesh on both sides. Netting or film may prevent plate glass flying but will rarely hold it in position after breakage. A neat appearance to the street front windows of an important building is very desirable and so is their protection against weather.

Therefore, boarding up, or if natural lighting is desirable, the substitution of a wood grille with small panels of wired glass in place of the plate seems the best solution.

2. *Glass in other external walls:* This is usually of light weight in small areas. Textile netting firmly glued on is the easiest "all-purpose" protection. But it diminishes light, gets dirty and cannot easily be cleaned. It would therefore appear that wire mesh screens, with a stock of glass substitute material kept ready would be the best solution.

3. *Glass in internal partitions, etc.:* Glass within a building is not so liable to be broken by blast, but it may be so broken and should be thought about. Except for that immediately adjoining doors kept open, glass in corridors, stairs, lift casings, etc., may be left untreated since few people are likely to be near them except at rush hours. The bulk of other internal glass is that in partitions between or adjoining working spaces. This should be protected from fragmentation in the cheapest way—by stout paper or textile netting on both sides.

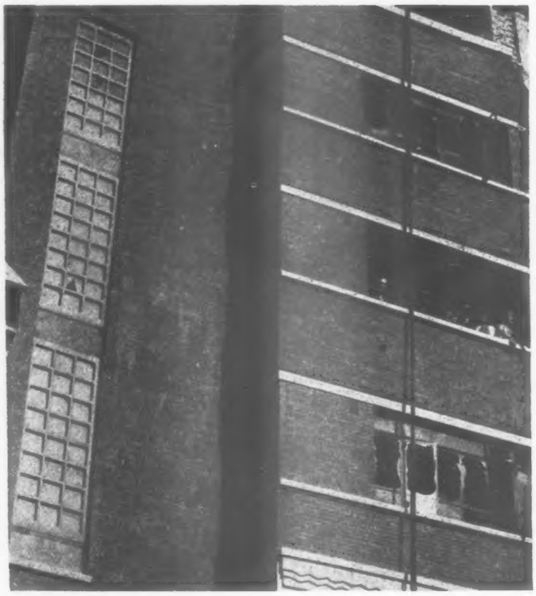
Special attention, should, however, be paid to one point in connection with these partitions. Damage to office buildings by fire often exceeds that caused by blast, and there is very good reason for increasing the number of fire checks in large office buildings, particularly where current files, accounts, etc., are left overnight in the office spaces. This can be most easily done by glazing the partitions around filing and accountants' rooms with wired glass.

4. *Glass in Roof Lights:* This problem is dealt with later under Factories.

2. SHOPS AND RESTAURANTS

IN these buildings protection against flying glass and consequential damage is of very great importance. Not only the staff, but customers, goodwill and stock

This shop, which is in a dangerous area, has removed its plate glass windows, boarded up most of their area and established small displays fronted with polished wired plate.



Left, wired glazed window pierced by bomb splinters. The velocity of the splinters and the relatively little damage done by them and the accompanying blast to the glass may be judged by the holes made by the splinters in the cast iron framing and infilling panel above.

Right, a suction wave which has pulled out ordinary glazing in steel casements has had little effect on 32-oz. sheet rigidly fixed in reinforced concrete framing on the stair to the left.

are concerned and much greater expense is justified. Precautions must not only be effective, they must look effective and if possible be elegant at the same time, and a very careful examination of all factors is justified.

The biggest problem is plainly that of shop windows and shopkeepers' keen dislike of obscuring them. Now that bombing has begun in earnest, however, the public have a keen dislike of passing such windows during frequent alerts, never mind loitering to look in—and it seems extraordinary that so few big shops have so far acted on this change of attitude.

The obvious solution is to remove big plate glass windows and to substitute either—

(1) Small displays glazed with wired plate glass or toughened glass (with a notice drawing attention to the shop's care for the public), or

(2) A wood grille similarly glazed, or (3) A glass-concrete front.

Such a change costs money but in certain areas of London, and possibly other big cities, it may be only a matter of time before the existing windows are cracked or shattered and therefore there is everything to be gained and nothing to be lost by immediate action.

The treatment of plate glass windows on upper floors depends on their size. If large they should be taken out and smaller areas of cheaper protected glass substituted. It should be remembered that in most stores good natural light is no longer necessary on upper floors over such big areas.

Internal glass wall finishes, doors, partitions, display counters and light fittings constitute the third big problem for shops and restaurants. In general where these are of heavy-weight glass they are not liable to be dangerous when a bomb explodes at a reasonable distance outside the building; but lightweight glass—such as many light fittings and glazed partitions—should be taken down or protected.

Roof lights should be strongly protected in the manner described for factories.

Finally, it should be emphasized that in most shops additional fire-checks are much more desirable than in offices: the aim should be to split up the shop into as many "cells" as possible by wired glass or copper-glazed partitions or by fire-resisting doors.

4. FACTORIES

THE primary problem of glass protection in factories is that of roof lights, and the fall in production which may follow when unprotected roof lights are broken even over a small part of a factory is extremely serious. The protection of roof lights, must therefore receive the most careful attention, and where the factory concerned is engaged on war production a large expenditure is justified for a first-rate solution.

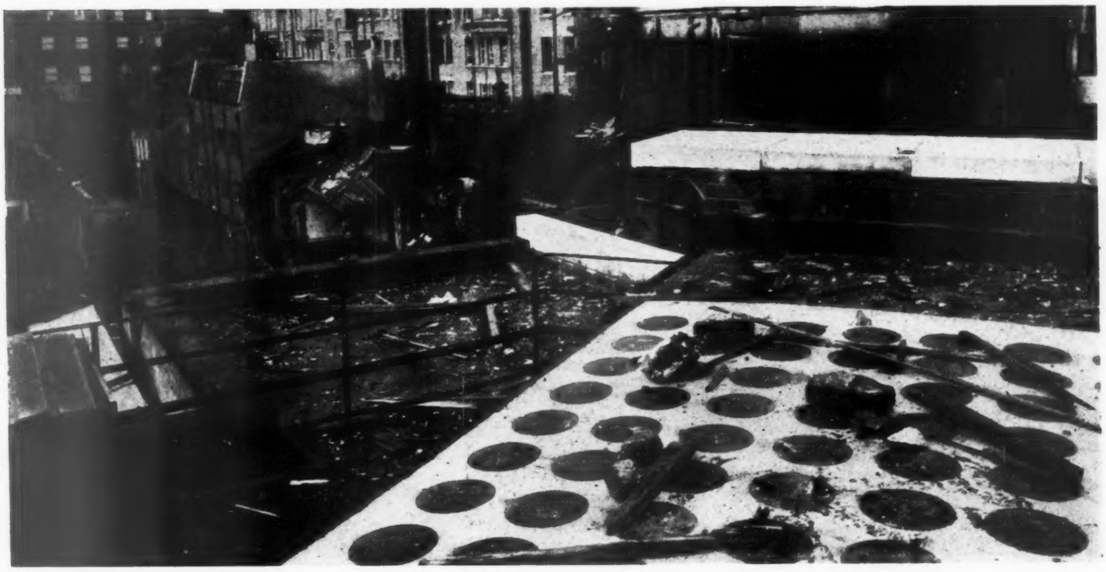
The best solution is to fit all roof lights with external sliding shutters which are weatherproof when closed and to fix ½-in. mesh wire netting below the glass as additional protection.

This solution is not, however, practicable in all cases and many factories have treated all their roof lights with hessian embedded in bitumen. This solves the black-out problem and provides weather protection when glass is cracked; but it is costly in electric light and very oppressive for the workers. But it is cheap in first cost.

A better alternative is to protect the roof lights of unimportant sections of the factory with hessian-bitumen and wire netting and reglaze the rest with wired glass. Such glass will need large mesh wire netting hung below it and will also require a roller blind system for blacking out, and for these reasons is less favoured than hessian-bitumen treatment. But it should be remembered that if the war is to last for two or three years more, natural lighting in daylight may be of considerable benefit to workers' health and that removing hessian-bitumen from roof lights at the end of the war will cost a large sum of money.

The other large problems concerning glass protection in factories are vertical windows, key points and plant and fire checks.

Vertical windows: The Ministry of Home Security recommends lightweight screens as the best protection for factory windows against splinters and weather. These screens can be either opaque or covered with some translucent material, but the Ministry does not regard trans-



lucency as very important—indeed since it prevents the screens being used for black-out purposes it may be considered a disadvantage. A large number of such screen types are described in A.R.P. Memorandum No. 12.* Essential qualities are that they should be light, strong, weatherproof, able to stop glass splinters and be in convenient sizes for easy handling. They may fit into window reveals or overlap the window opening and are most conveniently stored on wall hooks near the window for which they are used.

Key points : Important parts of the factory, such as switch and transformer rooms, telephone exchange, first-aid and fire points, require additional protection. Windows to such rooms must be blocked up, fitted with steel or timber shutters, or, in the case of rooms where daylight is important, be fitted with glass-concrete panels. Glass partitions separating such points from the rest of the factory should be removed and blast-resisting wall substituted. Observation panels in such walls should be small and of wired glass.

Fire checks : The risk of fire and damage it may cause varies with the factory's structure and contents. This risk has been diminished by the new system of fire watchers, but the need for fire checks has not. Oil bombs cause an extremely fierce fire, almost instantly, for a radius of twenty feet or so around their point of explosion, and it is obvious that in these circumstances even a frail fire check will be of great assistance to fire watchers until the brigade arrives. Such checks can be constructed in many ways, but one of the easiest is to reglaze existing partitions with wired glass or to sheath its glazed portions with plasterboard on both sides.

* See list of publications dealing with Glass Protection on page 486.

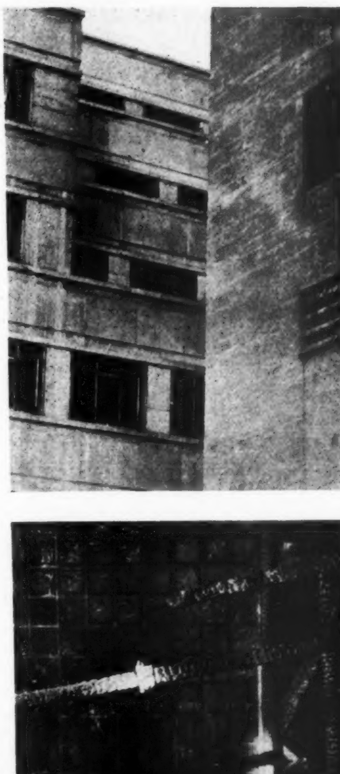
5. A.R.P. AND NEW BUILDINGS

THE tests described on previous pages show that, if it is impossible on the grounds of cost to replace all glass in existing buildings with " bomb-proof " glass, it is at least possible for new buildings to be glazed in an almost " bomb-proof " way.

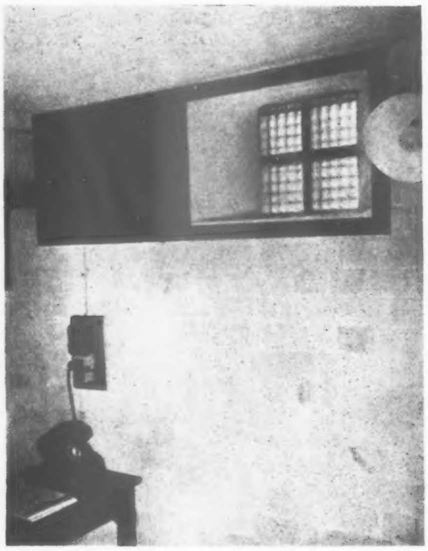
New buildings of the next two years will fall in large measure into three categories : camps and workers' housing, civil defence buildings, and factories. In all three types, all accommodation can be divided into that which needs only protection against distant bomb explosions and that for which protection is necessary against near effects.

It has been suggested that, in most of the internal spaces of wartime buildings, the problems of glass protection and black-out can be solved by having no glass. It is doubtful if this solution is wise. Glass substitutes are less efficient, more fragile and more of a nuisance than glass, and the complete abolition of natural lighting increases liability to disease.

A more probable solution for workers' housing is the use of wired glass in living rooms, of which the greater proportion would be rigidly fixed in a concrete frame with only a few ventilating openings. Alter-



Top, a roof light of glass lenses has been unaffected by a heavy bomb which caused severe damage nearby.
Centre, blast which has destroyed all glass of normal types in the two buildings shown has had no effect on strip lights of lenses set rigidly in concrete.
Above, glass bricks adjoining a well were subjected to fierce heat when a Manchester store was burnt out, and remained intact.



Glass bricks in A.R.P. Left, giving natural light to a surface shelter and, right, to a warden's post

natively, if shortage of time or materials makes this method inadvisable, a smaller amount of ordinary glass, in strip windows set high could be used in conjunction with weatherproof and glass splinter-proof blackout screens. In case of damage, the screens would provide protection against weather until the glazing was repaired. For sleeping quarters, strips of wired glass or glass concrete fixed over 6 ft. 6 in. from the ground seem the most sensible solution.

It is probable that all new factories will be designed from the outset to minimize glass damage and hold-ups following glass damage. Where space is available buildings will be well dispersed and consist of one floor only. Walls above 10 feet and roof coverings will be made as light as possible in all ordinary working spaces and be subdivided into as many standard panels as is practicable. It seems probable that the convenience of roof glazing and the small degree of damage which it suffers from a bomb bursting on the ground will lead to its retention over most workspaces. The consequences of glass damage to rooflights will be minimized in two ways: over most workshops the glass will be protected and blackout maintained by sliding shutters and all glass will be wired; over shops containing valuable mechanism where daylight is needed, glass concrete rooflights will be used.

Other important points in factories—switch rooms, telephone rooms, etc.—will contain no glazing. And where light transmission is necessary through fire checks these will be of glass-brick construction or of wired glass.

It can be assumed that every new wartime factory will keep on the premises a stock of materials for first aid and permanent repairs to all types of glazing and that the labour necessary will be kept readily available.

It may be assumed that A.R.P. constructions both for factories and elsewhere will normally be constructed without any glazing. But there is no necessity why surface shelters for use in daytime should not be provided with sufficient daylight to render their usual gloomy dampness more cheerful. Glass lenses set in concrete above head level have been approved for use in shelters by the Home Office.

Repairs to a hospital's windows

LIST OF OFFICIAL PUBLICATIONS on Protection of Glass

A.R.P. Handbook No. 5. Structural Defence: H.M.S.O. Price 2s.

A.R.P. Handbook No. 9. Incendiary Bombs and Fire Precautions: H.M.S.O. Price 6d.

A.R.P. Memorandum No. 12. Protection of Windows in Commercial and Industrial Premises: H.M.S.O. Price 4d.

A. R. P. Memorandum No. 16. Emergency Protection in Factories: H.M.S.O. Price 1d.

Your Home as an Air Raid Shelter: H.M.S.O. Price 3d.

British Standard Specification A.R.P. Series 48. From British Standards Institution, 28, Victoria Street, S.W.1.

War Time Building Bulletins Nos. 1 and 4. H.M.S.O. Price 1s.

Ministry of Home Security, Research and Experiments Department, Bulletin C.13. (Available free to authorized persons.)