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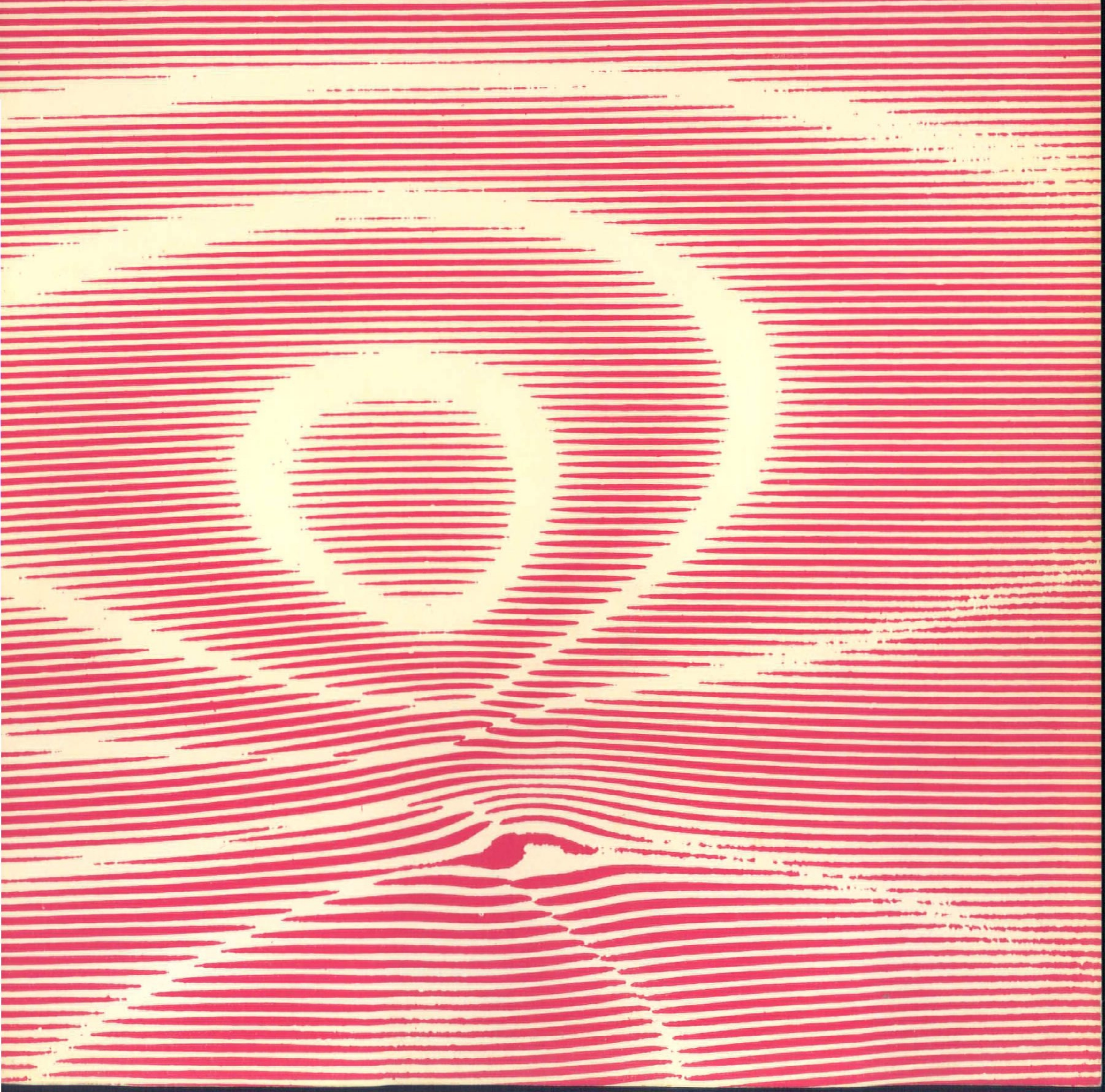

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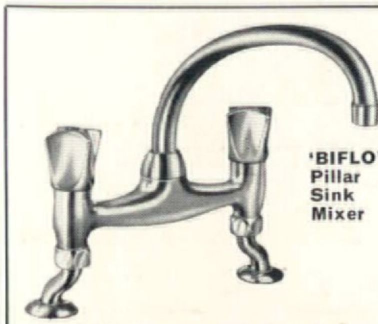

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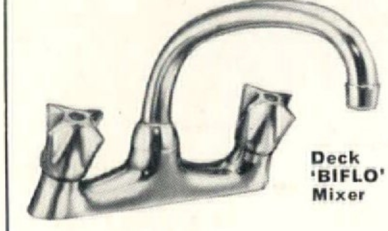

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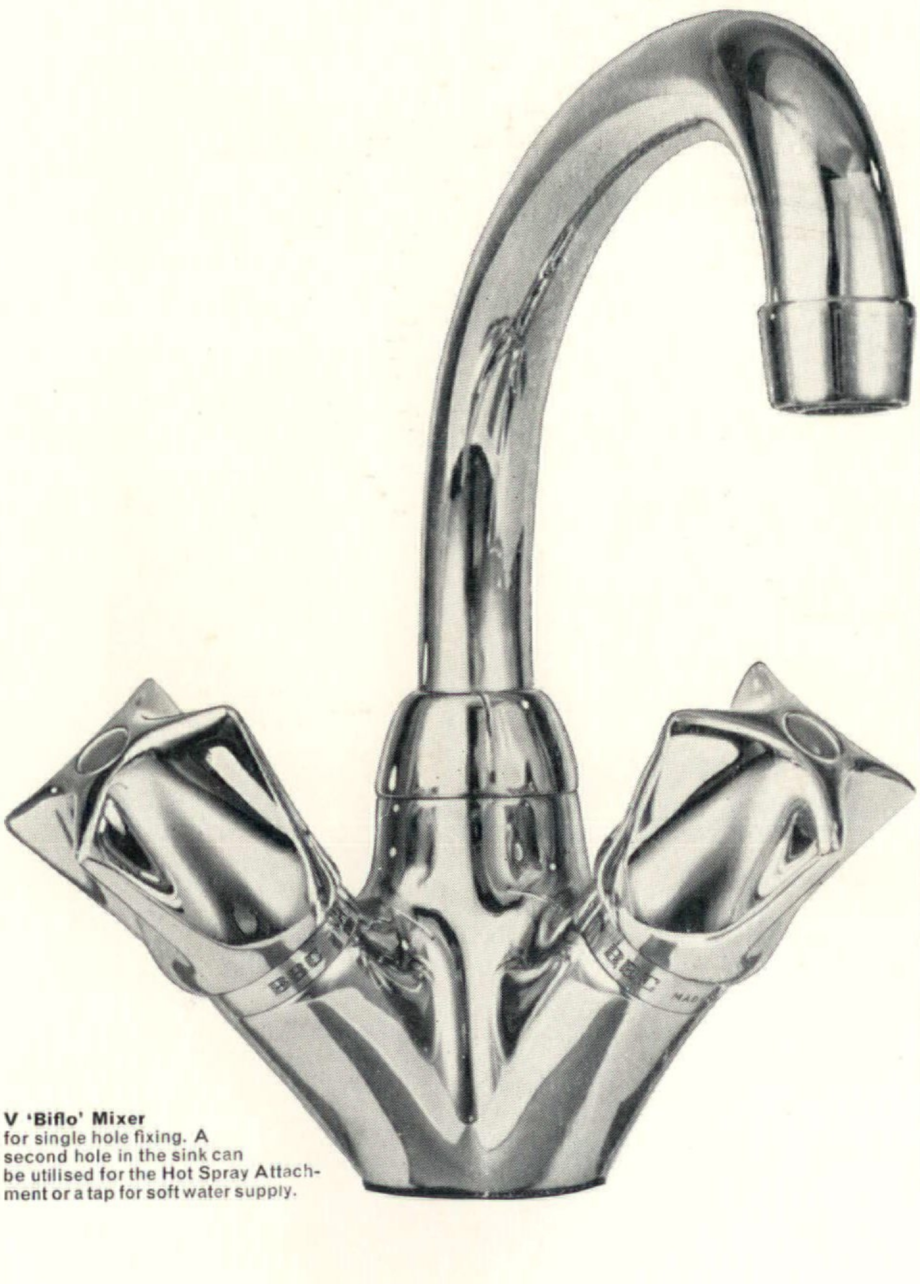

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Volume XXXVI January 1966

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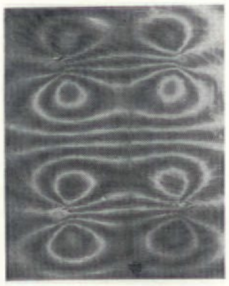

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Books

l'Utopia della realtà

Leonardo da Vinci Editrice, 1965

The book gathers the experiences of a third year course of design at the Milan Architectural School between 1962 and 1964 under the leadership of Ernesto N. Rogers.
The aim of the course was to give a sense of purpose to the unquestioning staleness and conformity of present-day training in architectural design.
The concept and meaning of 'design' as THOUGHT, INTENTION, DECISION, DEFINITION OF FORMS is here translated into a method of research in the light of scientific evidence.
However, as Rogers points out, if science is necessary for the definition and the pinpointing of aims, only architecture can translate and harmonize ethical principles into human realities.
Furthermore, one of the governing principles of the course was the refusal to accept the alienation of the individual from its context as well as the mass society that alienates the individual. Hence the title 'Utopy of Reality' meant as a choice between the easy and universal acceptance of utilitarian teaching conforming to the narrow material realism of the moment and the possible utopy of tomorrow built upon humanistic ethics and backed with the proofs of research.
Besides E. N. Rogers' commentary, the book gathers, for the first time in Italy, selected data on legal, pedagogical, typological problems related to the design of schools. *Germano Facetti*

The architecture of Prague and Bohemia

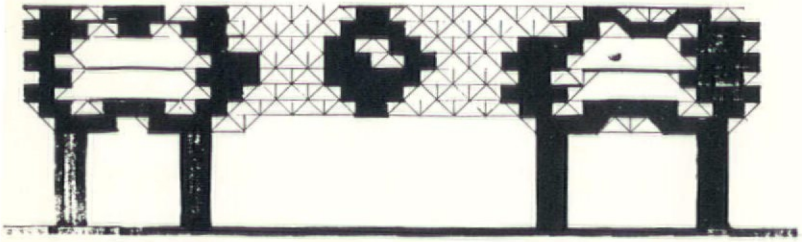
Brian Knox. Faber 63s.

Now that Czechoslovakia is easy to get into, Faber's have produced a new edition of Brian Knox's admirable retitled handbook. This can be read as an account of the different periods and architects, or used as a guide by visitors whose main interest is architectural (it warns about the poor condition of even the main roads, but has little other straight tourist information). There are 64 pages of photographs, of variable quality, and numerous plans and town plans. To anyone new to the subject it is hard going, simply because there is so much information. On the spot, however, it is clear and helpful, and its only defect is that Mr Knox does not sufficiently indicate what is worth visiting. He does not indicate, for instance, that, of the many Dientzenhofer churches in Czechoslovakia, only one, the great svatý Mikuláš in Prague, can rank with the Bavarian ones (Banz, Speinshart, and Waldsassen), or that many of the others are worth a visit only from someone with specialist interests.
However, despite the fact that the Austrian Hapsburgs treated the land during their long rule as a source of income, not as somewhere to build magnificently (Mr Knox discusses all this in excellent sections on the historical background), there is much for the architecturally-minded tourist to see. The border, with its barbed wire, soldiers with guns at the ready, and elaborate currency regulations, is the only discouraging thing. Once inside, you can roam as you will and enjoy the cheap petrol and hotels, and the friendly people.
Everyone should visit Prague, to whose splendour Mr Knox does full justice. The surrounding country has much to offer, such as the castle of Karlštejn, whose chapel still has its medieval paintings, and gilded vault, and emerald-filled windows. But the town itself is a unique spectacle, with the magnificent gothic cathedral, and the untouched baroque town below.
N. A. Routhledge

Chicago's famous buildings

Arthur Siegel, Editor. University of Chicago Press (6a Bedford Square, London, WC1) 7s. 6d.

Continuing with the architectural guide books, now comes an excellent and authoritative paper back on Chicago. Its history is as follows:
In 1957 the newly-formed Commission on Architectural landmarks and its advisors selected 39 buildings for preservation, and decided to prepare a guidebook to stimulate public interest in these plus additional buildings. Illinois Institute of Technology architecture students did the necessary measured drawings, while the photography students helped to photograph the buildings, supervised by Arthur Siegel who eventually edited the book. SOM prepared the indexed location maps.
Short introductory articles on the Chicago School are provided by Hugh Dalziel Duncan and Carl W. Condit, explaining respectively its principles and its practice.



1

Development over a Paris terminal

Yona Friedman

1
Typical section showing the spaceframe supported on piers. Living units, offices, walkways and roads are all threaded through the spaceframe

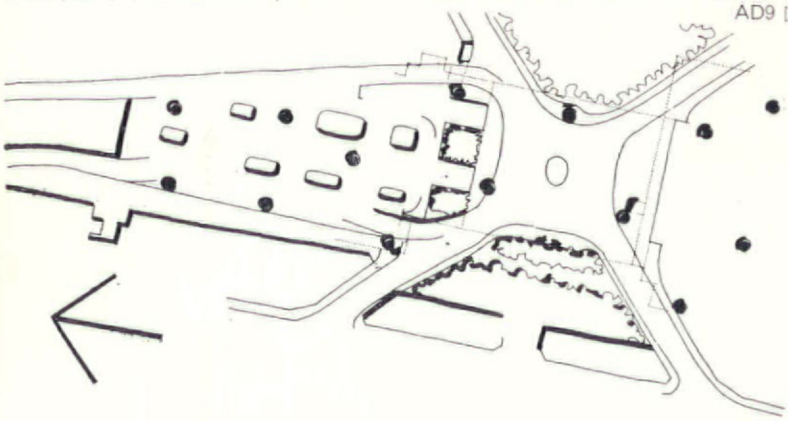
2
Plan of the first platform and column layout over the railway terminal

3
Grid layout

4
Block plan of the total development

Basically the development is to cover the railway leading into a Paris terminal This will be achieved by means of a 'spatial infrastructure' —a three dimensional spaceframe with seven levels, the whole supported on piers spaced at 35 to 60 metre centres. The infilling of the structure will contain shops and offices on the five upper floors with parking and through roads on the lower two.
The design is intended as a study only; it is not a definitive scheme but an outline of possibilities.
An area between 5×5m and 6×6m is left free between the structural members. Headroom is from 3 to

AD9 ▷



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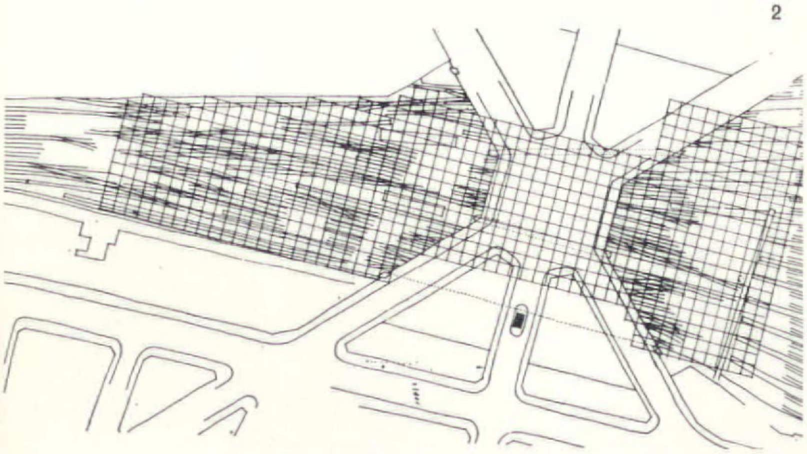

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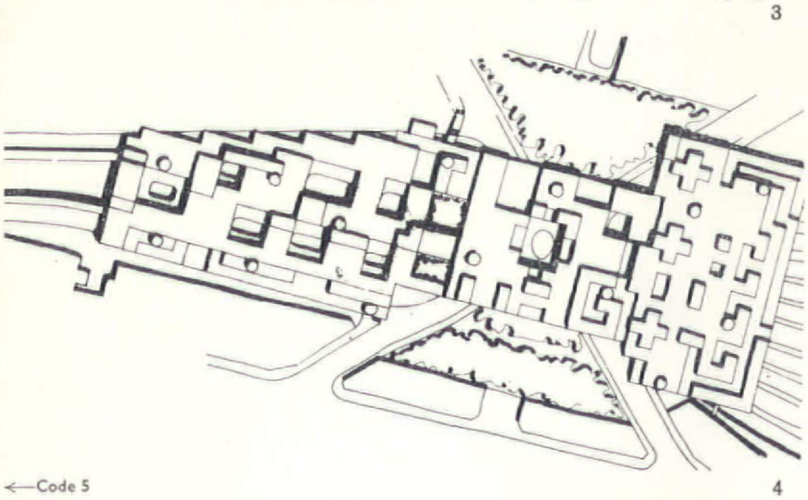

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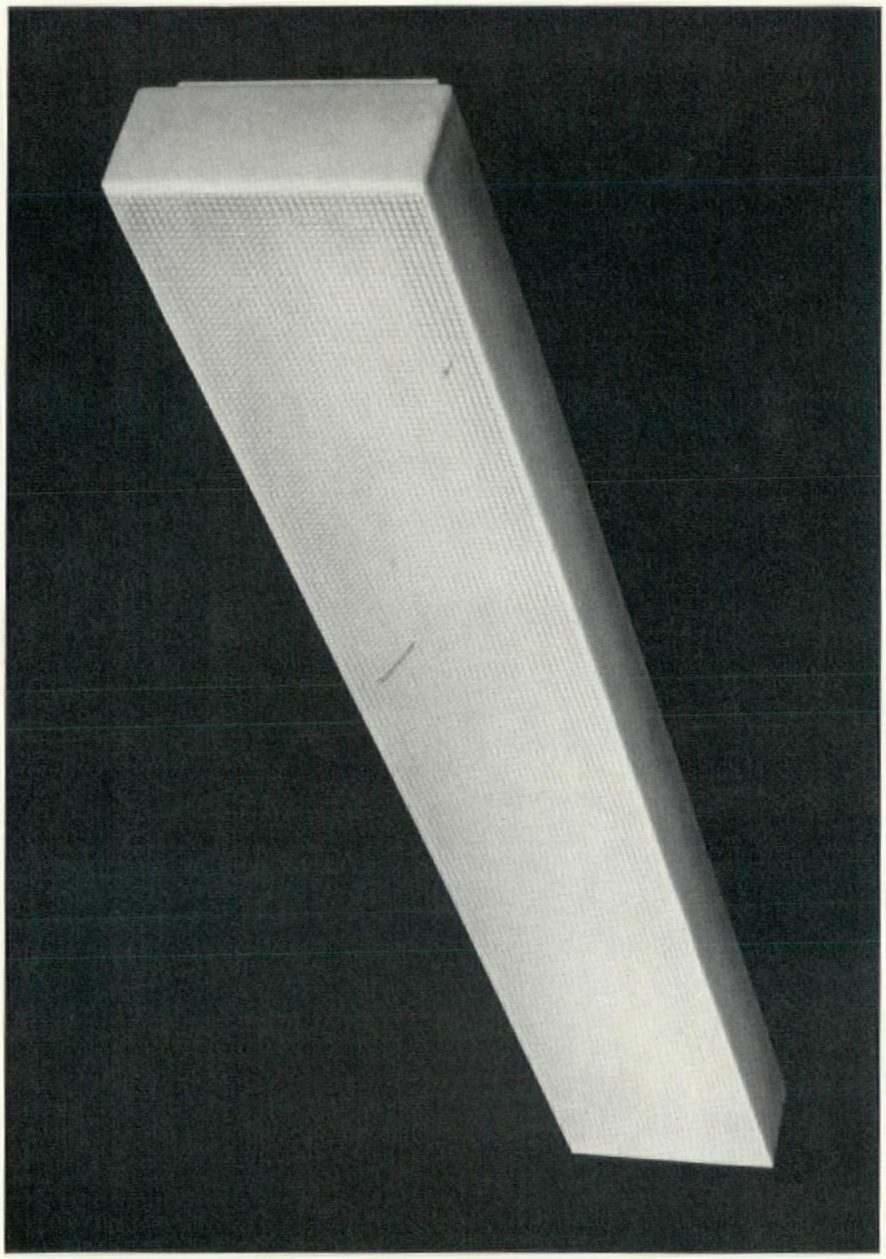

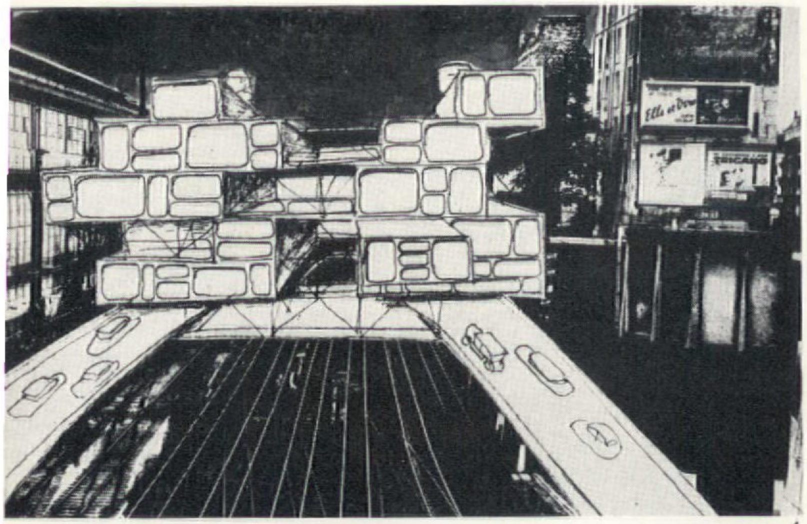

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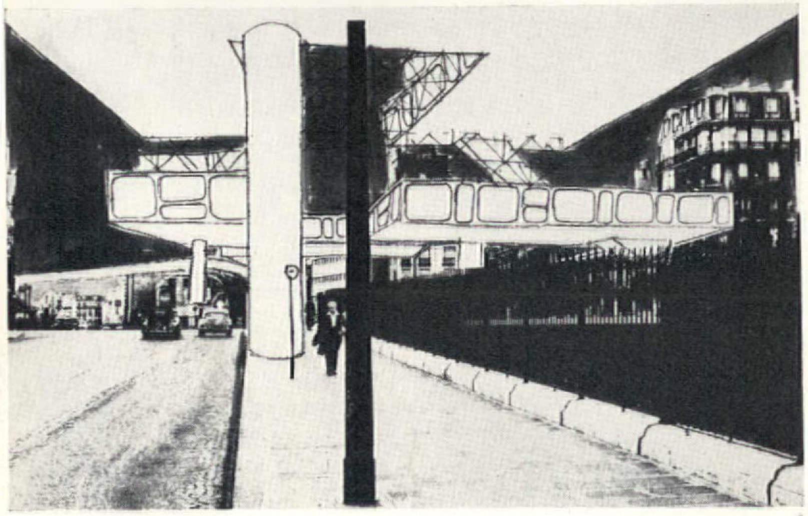


2

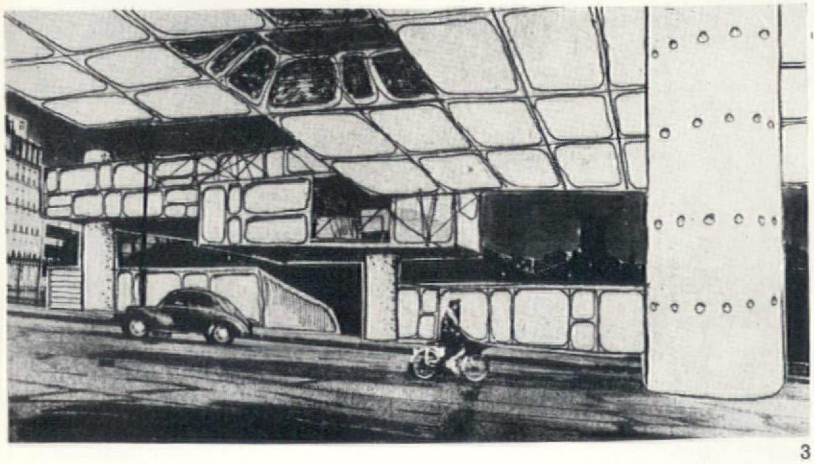
1
View of the main access roads from the north

2
The spaceframe over one of the roads flanking the terminal

3
The spaceframe suspended above the road network spanning the tracks

*Three preliminary studies have been made in establishing these figures.
1. Bridge Buildings 1958—span 60m, 6 levels, total weight 500kg/m².
2. Paris Spatial A.N.S. 1962—span 50m, 8 levels, total weight 1000kg/m²
3. Monongahela project 1964—span 80m, 6 levels, total weight 500kg/m².
Amount of steel required
Bridge Buildings, utilizing 50 per cent of the total area covered, 37kg/m².
Paris Spatial, utilizing 50 per cent of the total area covered, 25kg/m².
Monongahela project, utilizing 50 per cent of the total area covered, 25kg/m².

◁AD7
3·50m. On the circulation levels headroom is 4·50m minimum.
Assuming that 50 to 60 per cent of the ground area is built over on each level, the total area of building will be 200m².
Preliminary research has established that material required for the infrastructure will be in the order of 25kg/m² of steel on site for every square metre of floor area.*
The number of piers is estimated at 53, but details of their cost and foundation conditions have not yet been determined.
Piers were positioned to avoid almost entirely the compulsory purchase of land. Indeed all the infrastructure rests on ground belonging either to the railway company or the city of Paris.

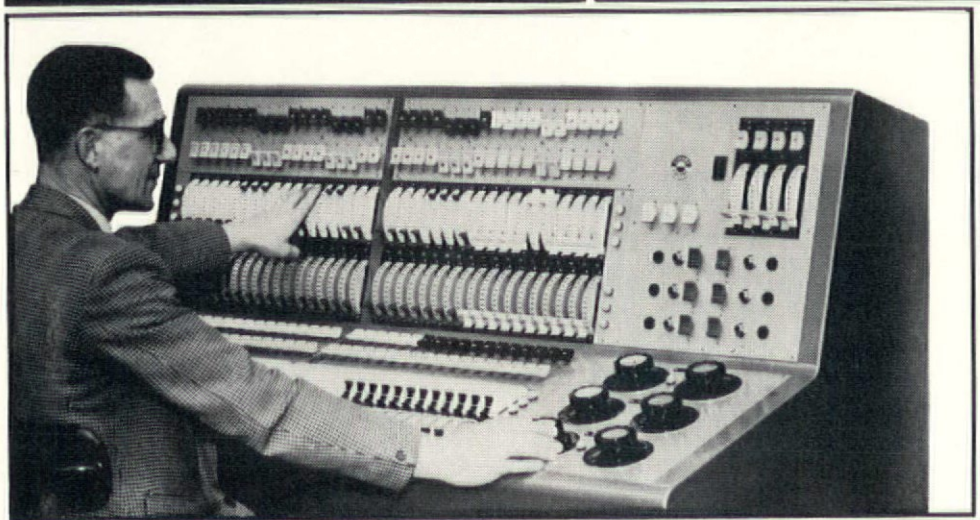


3

STRAND RIGHT THROUGH

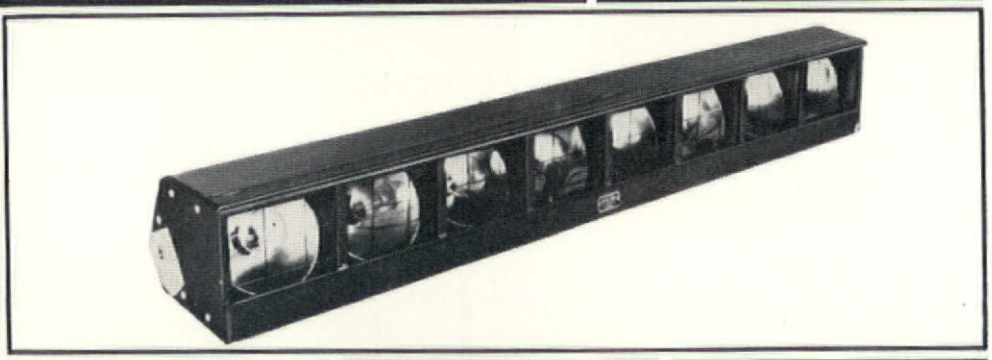
Britain's latest civic theatre, the Yvonne Arnaud at Guildford, is completely equipped by Strand. All stage lighting and lighting control equipment and the entire electrical wiring system throughout the theatre. Strand are world leaders in stage lighting design, equipment and installation. Write to Strand for copies of the quarterly "Tabs", "Stage Planning 1965", and the current catalogue.

Some of the Strand equipment installed in the Yvonne Arnaud Theatre, Guildford (architects, Scott, Brownrigg & Turner), is shown below.

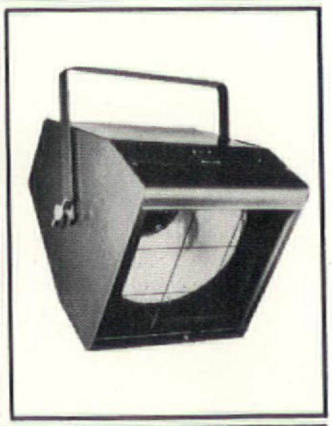


Strand system LC preset remote control desk for 72 all-electric dimmers.

Strand S type groundrow or footlight. 8 compartments of 150 watts to the 6ft. length.



Left to right:—
Strand Patt. 264
Bi-Focal Profile Spot,
1000 watt.
Strand Patt. 223 8-in. diam.
Fresnel Soft Edge Spot,
1000 watt.
Strand Patt. 60
Wide Angle Cyclorama Flood
500 watt.



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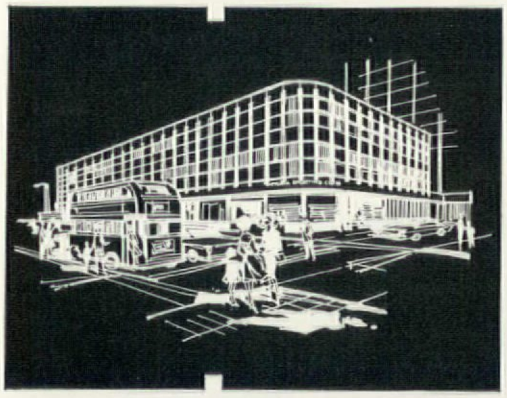

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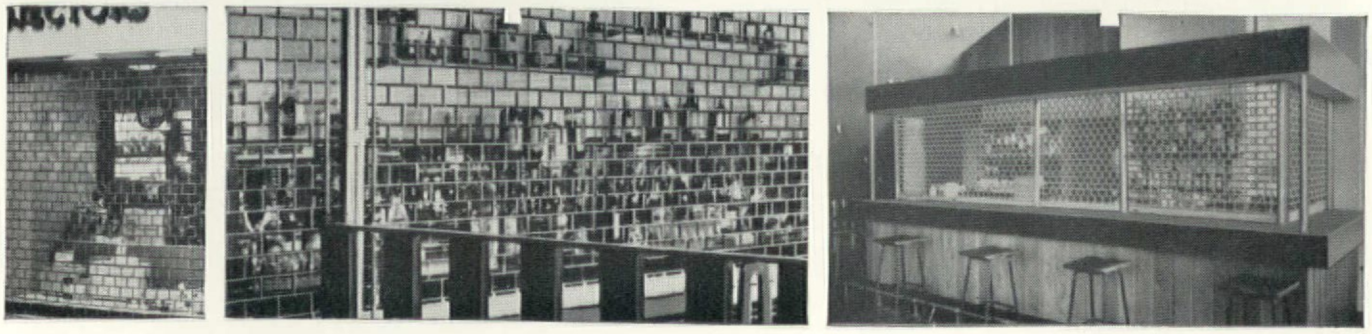

HOPE'S aluminium double hung sash

THE TIMES

Architects: Ellis Clarke & Gallannaugh

Consultant Architects: Llewellyn-Davies Weeks & Partners

Contractors: Trollope & Colls Ltd

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SOME GLAZING DEVELOPMENTS SfB (31) UDC 69·028·2

The window today, whether as a force in the total environment or as a single component with specific details, is in the process of fundamental re-appraisal. In this advertisement we at Pilkingtons review one aspect of this change—some innovations in modern glazing detailing. Later we hope to present some of our views on the role of the window itself in relation to current knowledge.

Frameless glazing
Examples of frameless, or sashless, glazing of large size sheets are rare in Britain. By frameless glazing we mean an opening light without a frame in the conventional sense but set in a surround of one sort or another. One medium-sized example of such a window from the Modolite range by H. C. Janes Limited is shown in **(1)**. Better known perhaps for frameless horizontally sliding panes, this firm has now introduced frameless *vertically* sliding *double glazed* windows—very much a new development. The glass is set in a Californian Redwood surround and is $\frac{3}{16}$in. thick drawn sheet with polished edges. The air-space is 2in. Both inner and outer panes slide for direct, or indirect, ventilation. The glass slides in rigid vinyl tracks into which double pile weather-stripping is inserted. With special coupling units the windows can be combined with fixed panels glazed with 'Insulight' Glastoglas in stock sizes, to form composite windows.

Another example of unframed glass panels is found in the Naco Reversible window by N. V. Appleton (UK) Limited. **(2)**. This window in an anodised aluminium surround is a development of the firm's range of glass louvres. Its large pane pivots horizontally and is fully reversible for cleaning. Sizes are from 2ft 4in to 4ft 8in high (in 4in. rises), with one or two louvres, in widths up to 3ft 6in. The $\frac{1}{4}$in. glass can be either clear or obscured and have either smooth or arrissed edges. The glass sheets close against each other horizontally and are weatherproofed around the perimeter by a pile strip in the surround.

An older, and larger-sized, example of a completely unframed opening light is to be found in the 3-floor podium block windows of the Pirelli tower in Milan—finished in 1960. **(3)**. Here the toughened glass panels are some 3ft by 6ft and pivot horizontally. They close against neoprene gaskets onto which the glass is firmly pressed by cam action fasteners on the bottom edge of the panels.

Rotating windows
The ISAL-Rotating window is another Continental development and is made by the firm of Schmidlin AG in Aesch, Switzerland. **(4)**. The double glazed window can be revolved through 360° in the vertical axis. A braking device secures the window in any desired position. Apart from the obvious advantage of ease of cleaning, the window is offered primarily as a versatile means of controlling solar penetration into a room. A vertically sliding venetian blind is incorporated into the window frame, on the outside of the glass, and this revolves with it so that the shaded window can be moved as the sun goes round. The blind is controlled at any position by the crank in the top corner of the surround. Depending on the season, the blind can be either inside or outside of the building. In summer, this means that the blind can be exposed to cooling external air to carry off heat build-up which is otherwise passed from the blind into the room. When closed, the window is weather-proofed by a sliding gasket (a) set around the perimeter of the surrounding frame.

Modular windows
The standard metal windows which were introduced 45 years ago were one of the first steps in this country in the mass production of machined building components. These windows, which were based on a unit width of 1ft 8in. and height increases of 1ft were never entirely popular with designers—despite the introduction of the Z range based on a 2ft width unit in 1952. In 1960 the Metal Window Association decided to review the design and in collaboration with the RIBA appointed the architects Edward Armstrong and Frederick MacManus to produce amended designs. Their 4in. module design followed consultation with the RIBA, the Interdepartmental Government Committee, the MoHLG and the Modular Society.

For the first time in metal window design, all aspects of performance were examined.

The Module 4 range which has 135 basic shapes and sizes was first introduced in February 1965. **(5)**. The improvements are, briefly:—replaceable weatherstrips as optional extras; new fittings in keeping with other ironmongery ranges; redesigned doors so a single leaf is 3ft wide overall with a solid lock rail lining up with two of the required cill heights; for small openings, casements on extended hinges are used but for large areas pivoted windows, for easy cleaning and weatherstripping, are used; top hung ventilators can be either opaque or glazed; the maximum opening light size was determined by 32oz glass sizes—i.e. 4ft 4in. overall frame size—and plate or float can be used in large fixed lights; all dimensions are from module line to module line, the actual frame being $\frac{3}{16}$in. less overall; for vertical dimensioning a 4ft module was chosen in a series of 8 multiples and a 4in. horizontal dimension was used, in conjunction with a 4in. solid filler piece, ranging from 4in. (solid) to 6ft; finally, any component can be linked to any other to form composites.

Acoustically controlled window
In an attempt to control external noise entering buildings, the Building Research Station, in collaboration with the London Borough of Hillingdon, has developed an acoustically controlled double glazed window which opens and shuts automatically according to outside noise levels. A prototype was installed in the Harlington Secondary Modern School, which is $\frac{1}{2}$ of a mile from one of the main runways of London Airport. **(6)**. Aircraft noises over the school commonly reach 85 to 95dB.

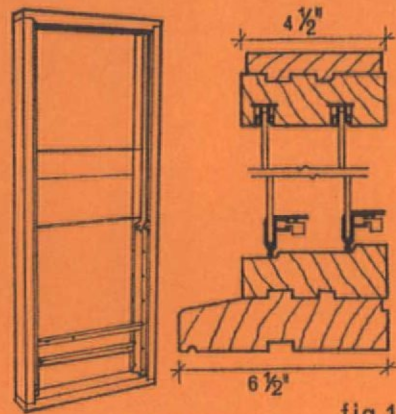
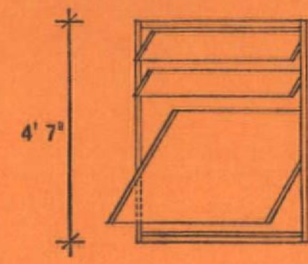


fig 1



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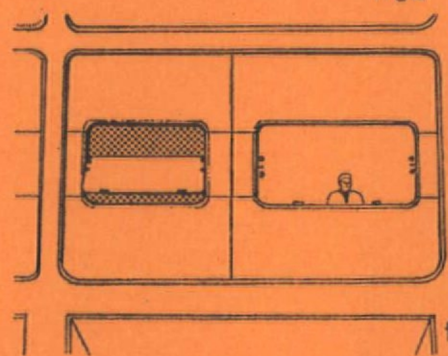
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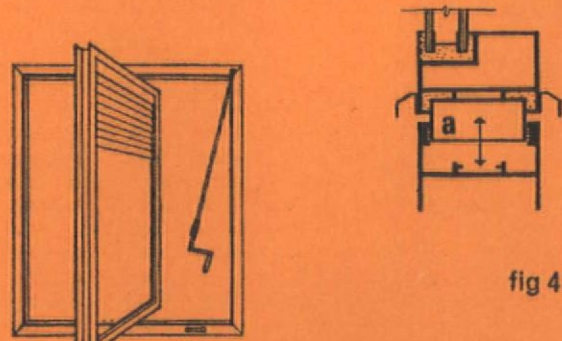


fig 4

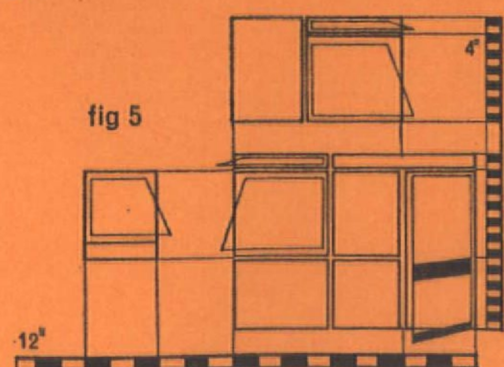


fig 5

Wherever the noise source is intermittent, the device is put forward as an adequate and less expensive alternative to fixed double windows, which demand full air conditioning. Tests are at present under way to see whether the window provides adequate ventilation. This will depend on the extent of use but, even at peak traffic times, it is not expected to be closed for more than two thirds of the time.

The window is operated by a microphone (d) on the roof actuating a relay switch (f) when the noise level rises or falls below 60dB. This switch operates a hydraulic power unit (e) which in turn operates small hydraulic rams (a) concealed in the window surround. These rams move connecting rods to open or shut the window. When closed, the window, which has an 8in. airspace, gives the same protection against external noise as a fixed window with the same airspace. The mechanism has a built-in safety device and can be manually overruled by switch (b). A patent for the invention has been applied for and the rights have been assigned to the National Research Development Corporation. James Day Fabricating Engineers Limited, London S.W.14, manufacture the components under licence. Preliminary estimates suggest that it will cost from £200-£300 for the equipment to control ten windows.

Plastic covered frames

Building maintenance costs Britain some £900 million a year and uses 40% of the building industry's manpower. While window maintenance is but a small part of this enormous total, quite clearly maintenance-free components are of great value. One window of traditional material but untraditional weather resistant surfaces is shown here. It is made by Newsum Timber Engineers Limited, and is the Monza-Plast timber window covered in rigid white PVC. **(7)**. The design was first marketed on the Continent in 1958. The extrusion (a) is seamless and has a bolted and gasketed corner joint. It is claimed to give complete protection to the timber to prevent distortion due to humidity changes and is said to be colour-fast for 20 years. The windows can be single or double glazed with 'Insulight' Glastoglas using the same sections. Glazing is from the inside. The range includes both traditional and modular sizes.

Glazing into masonry

Techniques for glazing straight into masonry have appeared intermittently for many years. However, it is only with the development of new forms of mastics that the method has really become capable of full exploitation. In his house at Harpenden, Herts., Povl Ahm (associate in Ove Arup & Partners) and his architect Jorn Utzon (Sydney Opera House) designed the 102ft long south wall and the 20ft east wall in glass from floor to ceiling, an average height of 9ft. **(8)**. All the fixed panels in the glass walls are factory-made double glazed units to reduce heat loss. These are taken directly into chases in the concrete at the window head, filled with Evoflex non-setting mastic (b) and sealed with $\frac{1}{8}$in. Evostrip (a), and into frames flush with the floor level. As the main point of the glass walls is to link the inside with the outside, this form of flush glazing prevents the sweep of the eye from being interrupted as one looks through the window.

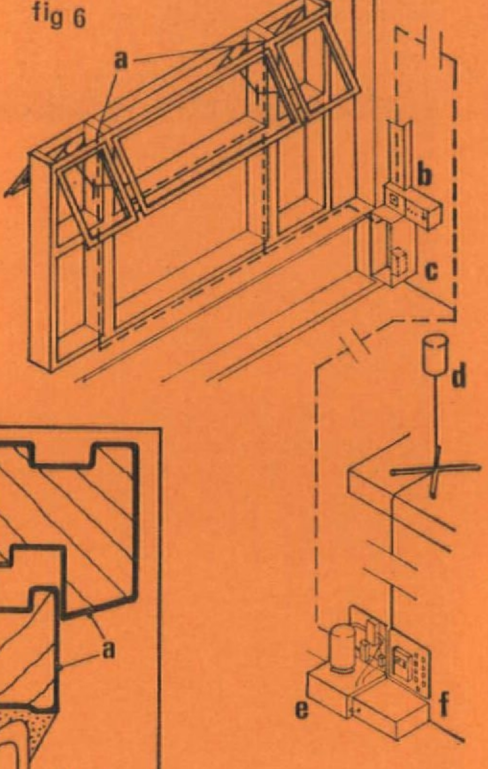
A somewhat more dramatic example of this technique is in Minoru Yamasaki's synagogue for the North Shore Congregation Israel community in Glencoe, Illinois. **(9)**. This large building stands on a bluff overlooking Lake Michigan where gale force winds are common. It is of folded-slab construction in concrete. The pointed vaulting springs from ground level, not cornice level. These big arched panels, many of which are precast, are free-standing and make up the walls and roof. They are united by slender pin joints at eaves and ridge level. The long thin openings between the monoliths of concrete are closed with what one might call a free-floating window system. This form of 'flexible' glazing was evolved in order to withstand the building's quite considerable thermal and wind movements. These glazed areas are largely self-supporting as the glass, cushioned by polyethylene foam strips (b), is taken directly into chases formed in the concrete and held there by a load-bearing silicone sealant (Dow Corning 780) (a).

The glass, which is $\frac{1}{8}$in. opalescent golden amber, seedy, antique pot glass, is held $\frac{5}{8}$in. in from the back of the chase and $\frac{3}{8}$in. from each of its sides by the sealant whose high tensile strength (125lbf/ft^2) ensures that all static and dynamic loads are carried in the vertical joints. Thus no panel bears directly on the one below, which simplifies replacement. In the end wall windows shown in the sketch, the width is 44in. at the base, 50in. at the knee with, thereafter, a taper to zero at the ridge. The glass panels are 30in. high and are joined horizontally by a lead came into which a stiffener is also incorporated. The panels are divided visually by leading on the surface of the glass to form a repeated pattern of opposing arcs. The system was tested as capable of withstanding winds of up to 100 mph exerting pressures of about 25lbf/ft^2 and when failure did occur it was in the glass and not the mastic.

Profilit

No review of developments in glazing design would be complete without mention of glass wall construction in Profilit. This material was first put on the market in Austria in November 1957. The U-shaped channels of 10$\frac{5}{16}$in. wide, cast or wireline glass, are translucent and can be used to make glass walls of unlimited width without mullions. The height depends on the wind loading at the site. In this country, lengths of up to 20ft are carried in stock but longer lengths are possible to special order. On exposed sites, however, it may be necessary to brace the assembly with a horizontal support. The glass is normally installed in vertical strips in channels top and bottom of steel or light alloy, usually in any of the four arrangements shown in figure **(10)** (a,b,c,d). In the last year or two this material has been increasingly used in this country—often with considerable imagination. Quite clearly, it has immense possibilities in modern building.

fig 6



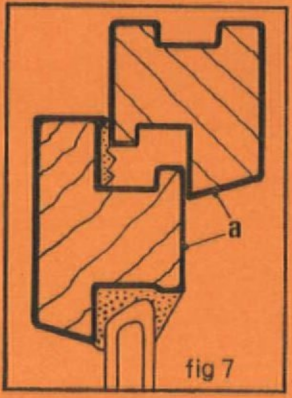


fig 7

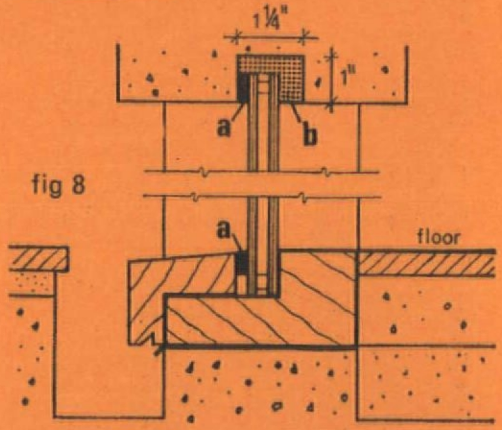
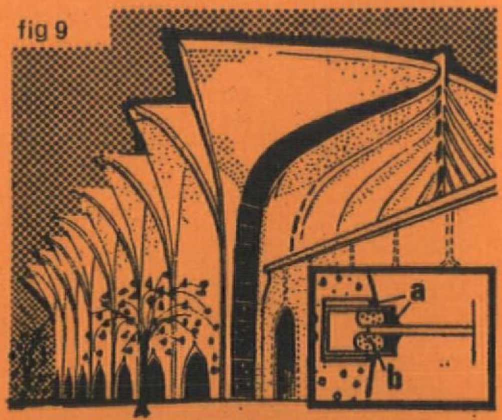
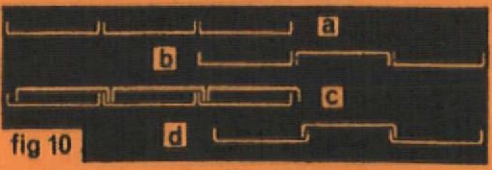


fig 8

fig 9





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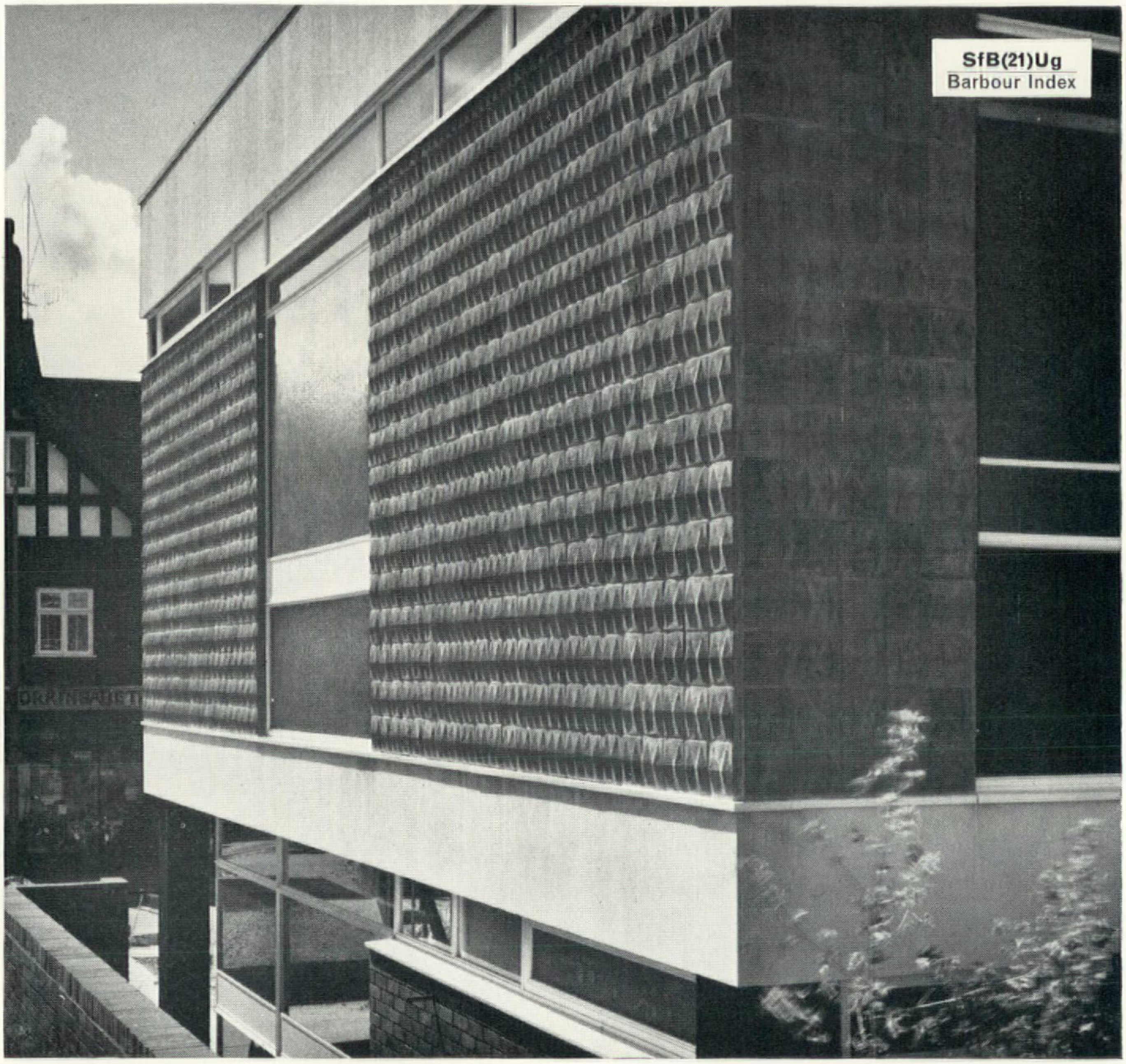
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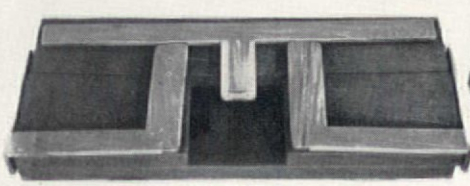

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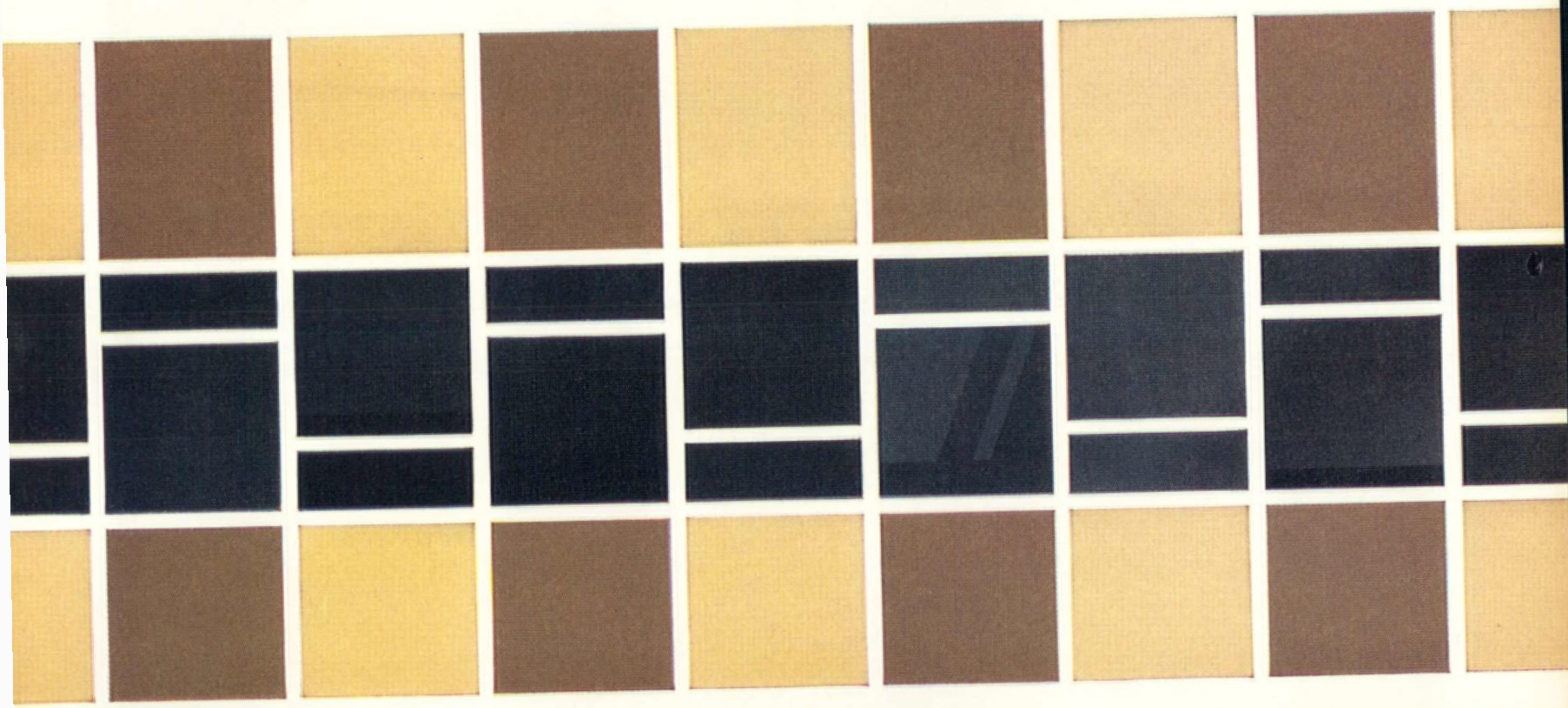

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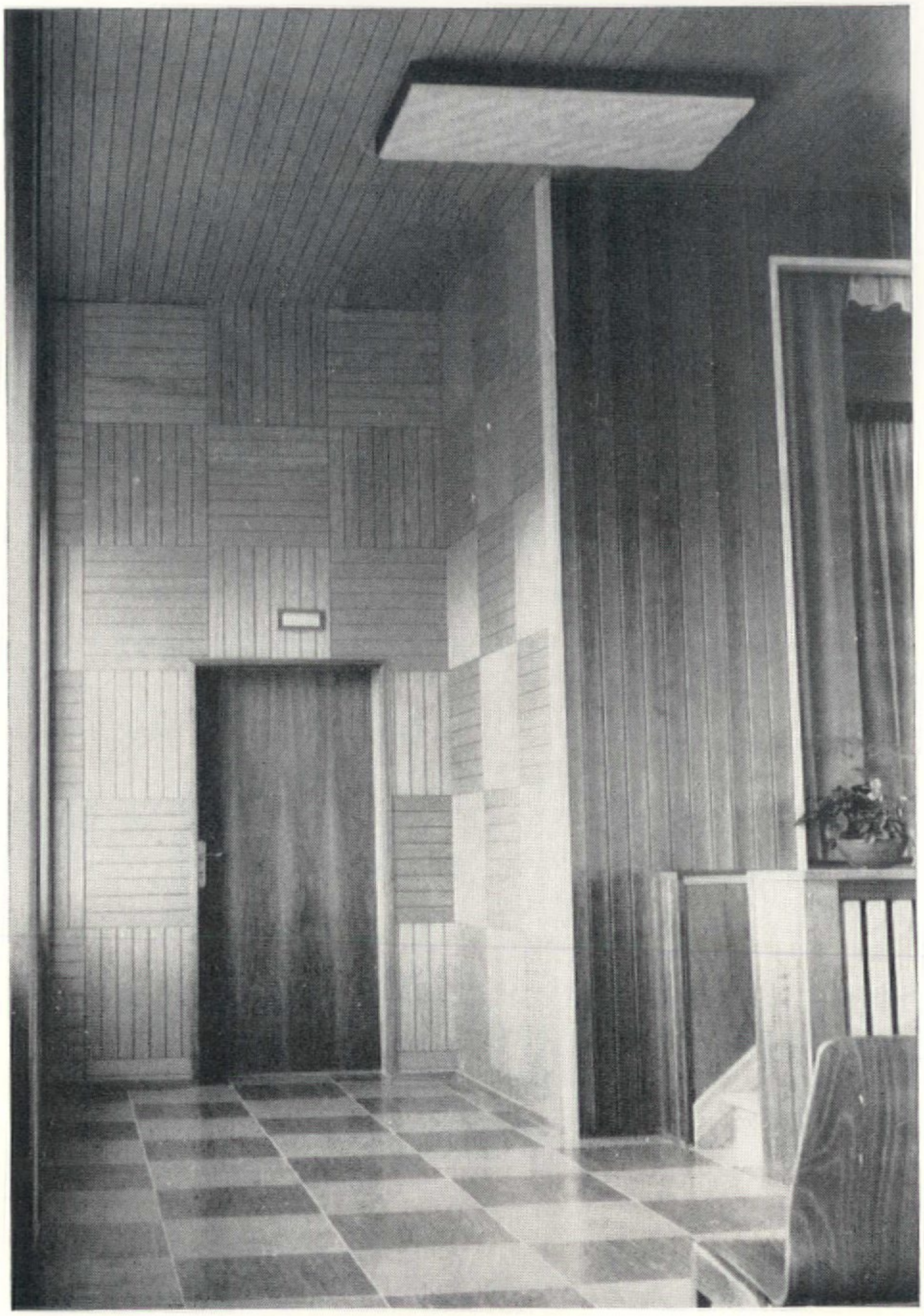

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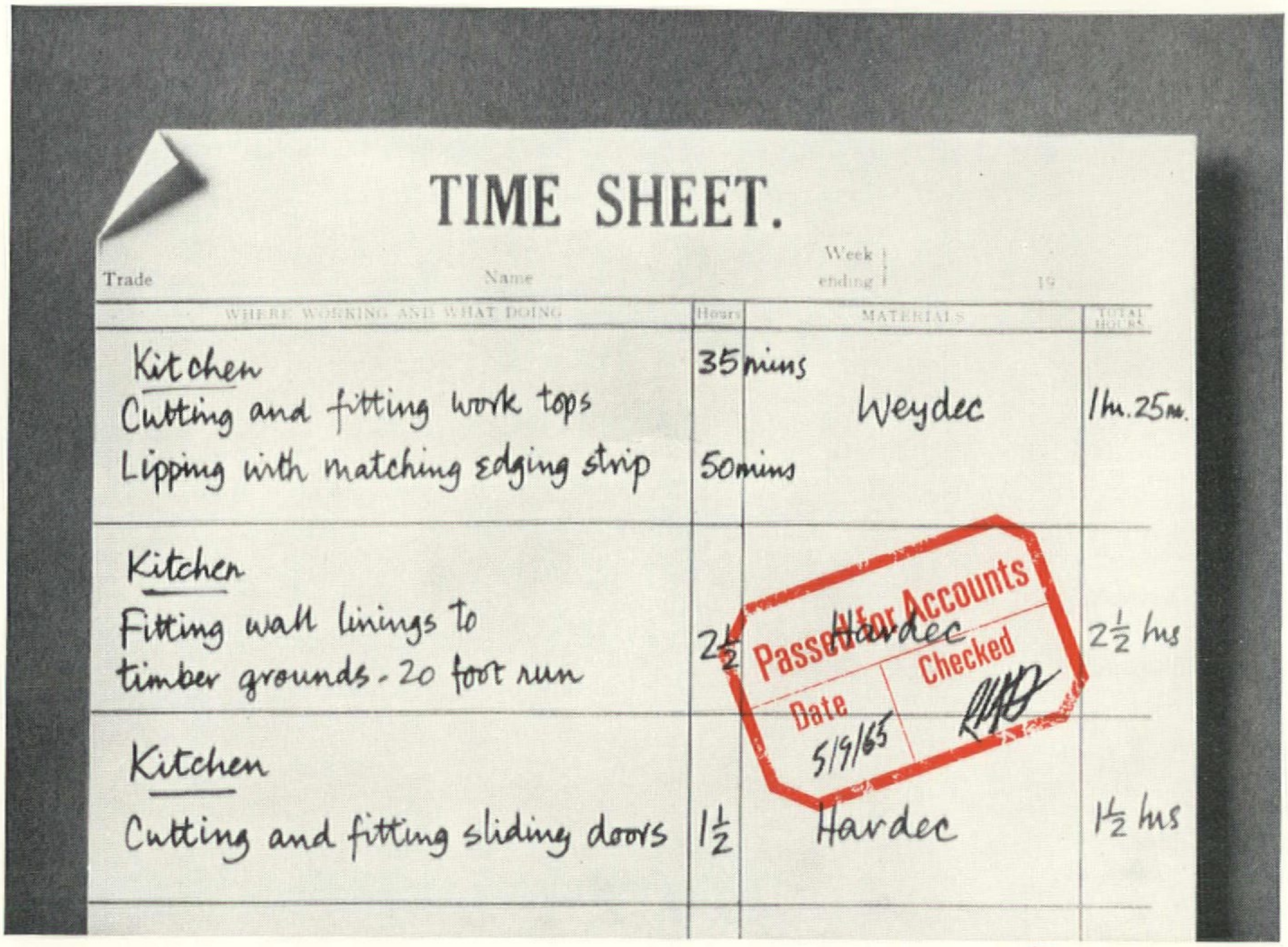

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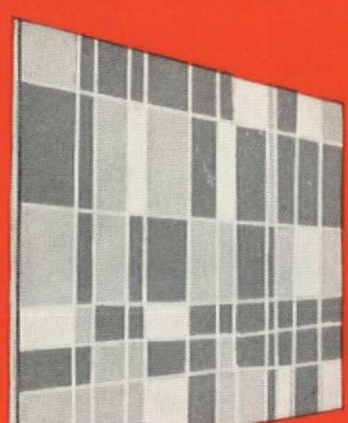

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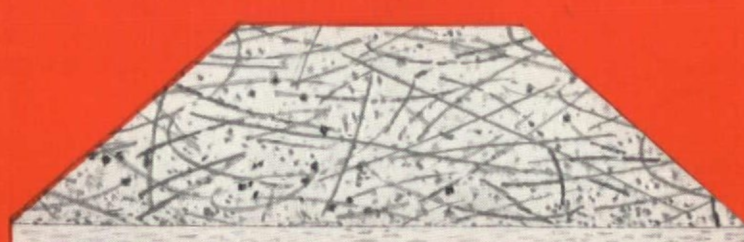

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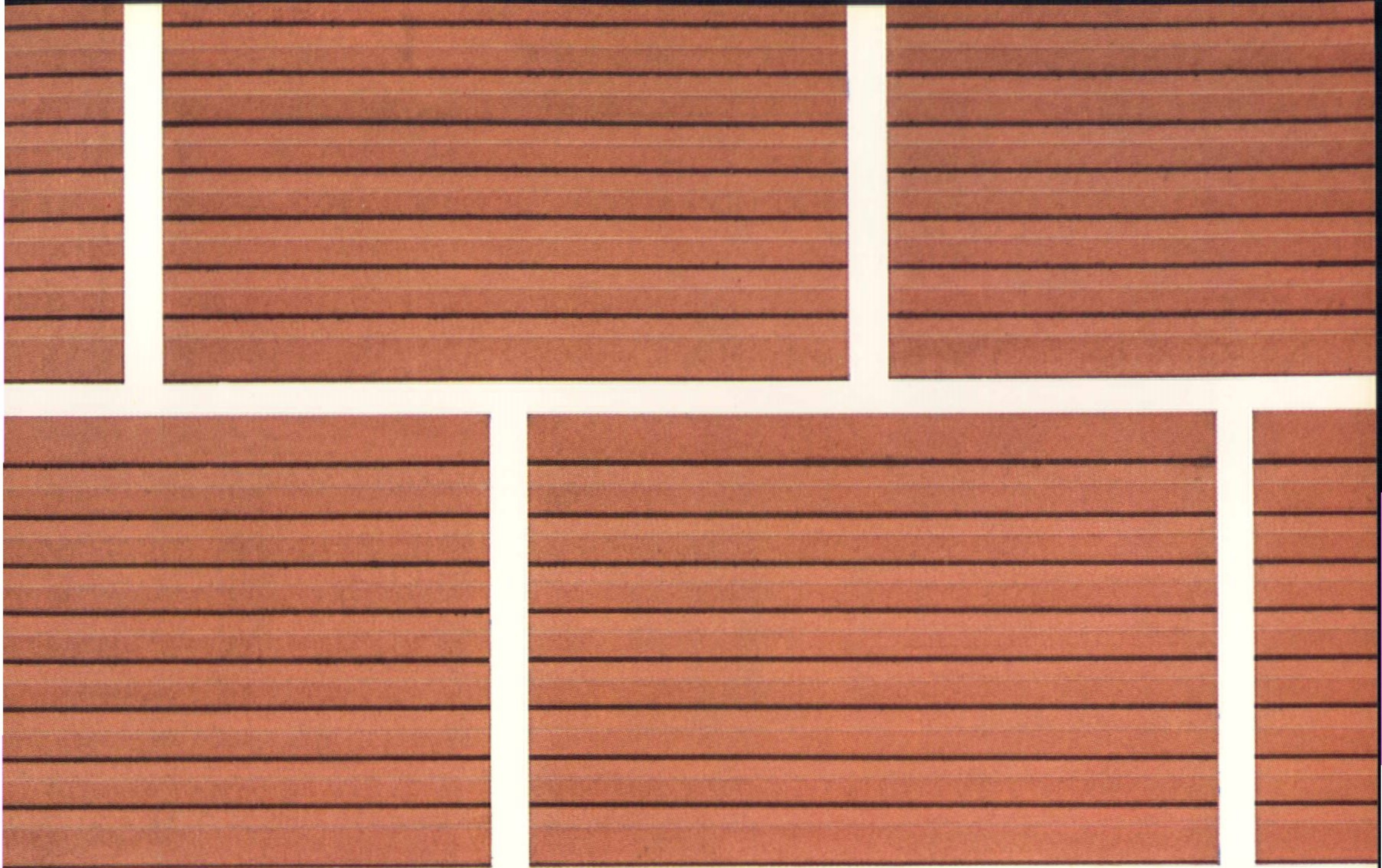

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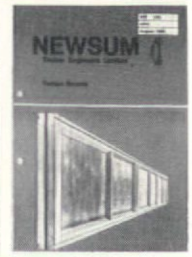

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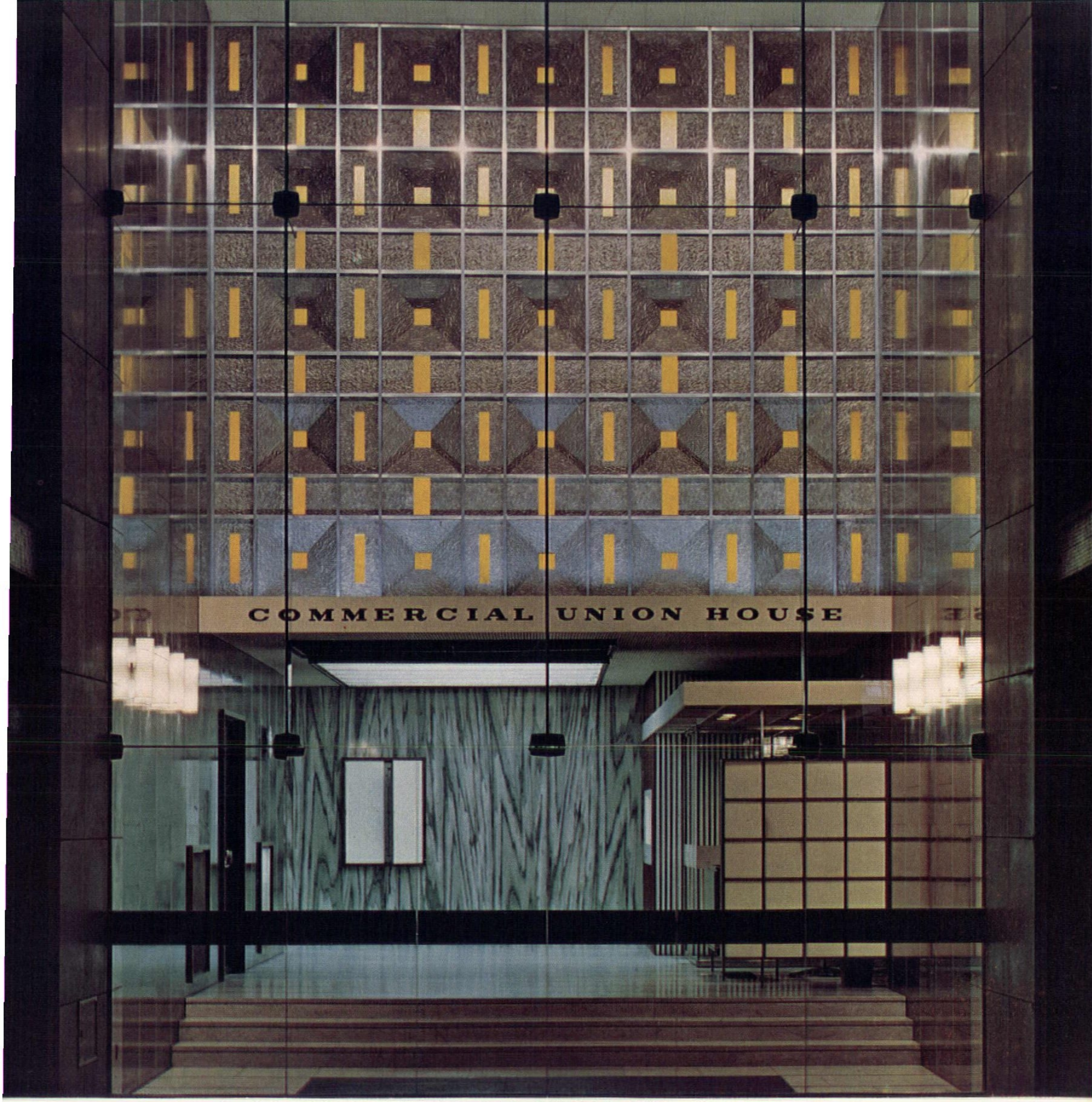
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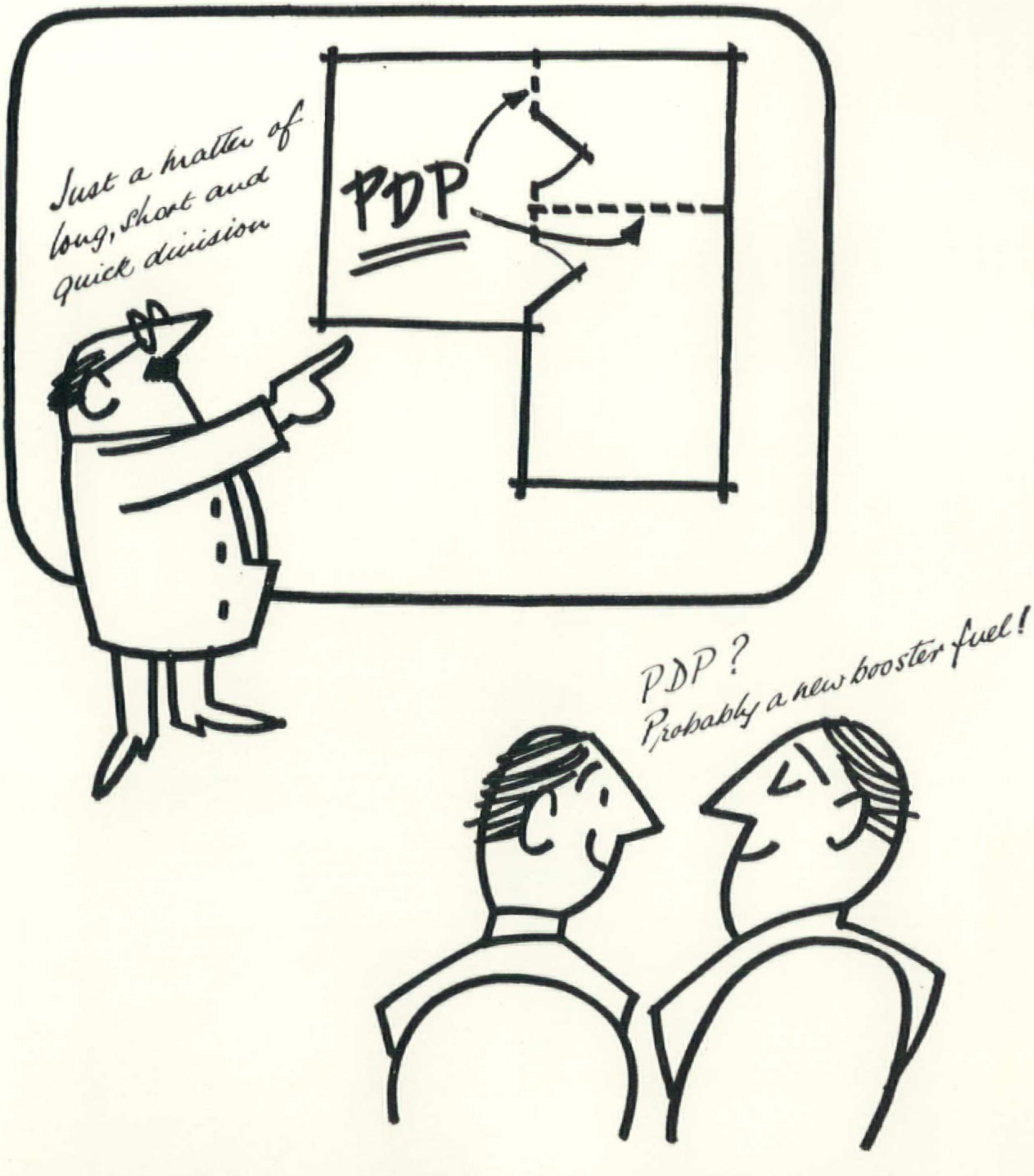

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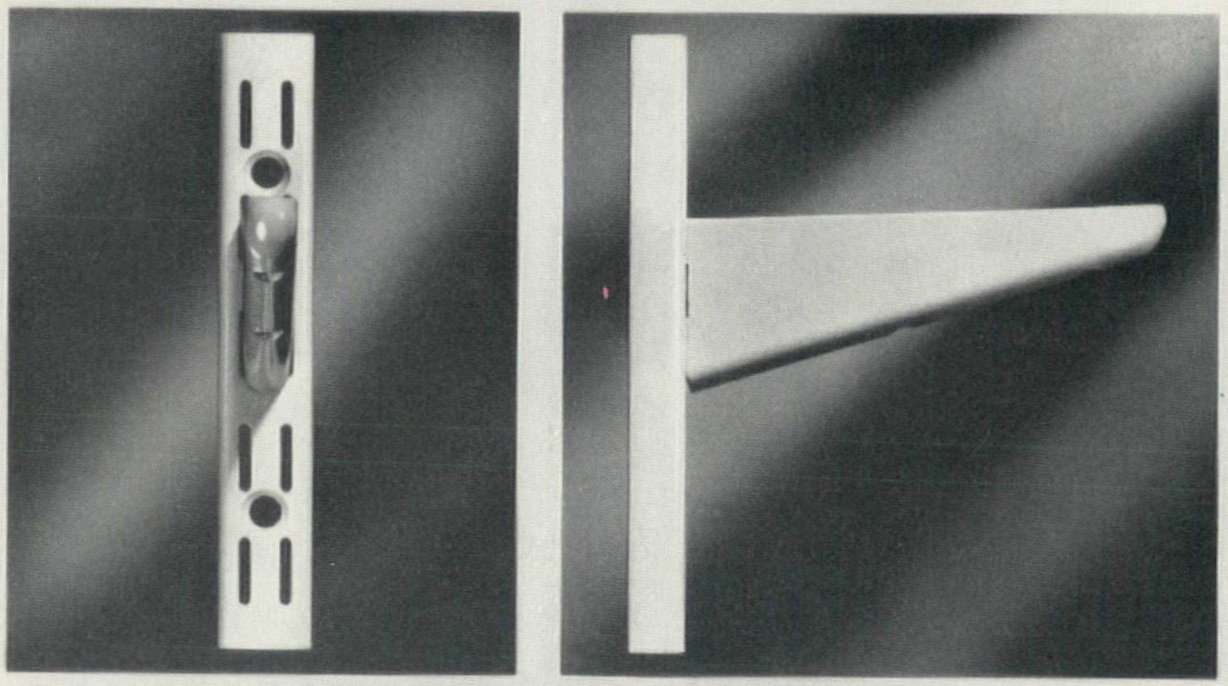

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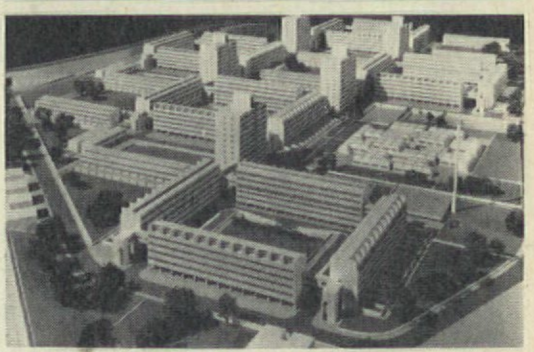
The month in Britain

Michael Manser

Mr Wilson opened the Building Exhibition and the *Architects' Journal* did an excellent breakdown of exhibits in the exhibition, and the organizers provided more overall visual order than before. Several symposia were held concurrently at Olympia, including one by BASA on Plug-in concepts and another by the British Iron and Steel Federation, which by contrast hardly excited the imagination or covered new ground.
The AA convened a Scale and Magnitude Conference at Sussex University to draw a picture of the present economic, social and political condition of Britain—and the need for comprehensive redevelopment programmes—and what this means to architecture and building.
The Architects' and Engineers' Joint Building Group held another meeting at the Institute of Structural Engineers to discuss standards of quality, and Leslie Marler of Capital and Counties and the Knightsbridge-Green-scheme-that-never-happened told the London Master Builders' Association, 'No one can disrupt the building industry, the whole basis (after agriculture) of civilization without the most serious, not to say disastrous, effects spreading to every corner of the country. I am not talking politics. This is plain common sense and should be shouted from the house-tops.'
Minister Pannell, erstwhile advocate of a Gothic extension of Westminster, talking to the RICS, took a different view and claimed, 'we are bringing in building licensing to ensure that the resources of the construction industry are used to the best advantage . . . what we want to do is be more discriminate'. The trouble is that discriminating against one kind of project does not produce the cash for another and the upshot may be a downsurge of the entire construction industry.
The Greenwich Theatre Trust appealed for funds for their rebuilding project by architect Brian Meekings, and the University of Nottingham started a new degree course in Architecture and Environmental Design. The foundation stone was laid for St. Paul's Cathedral competition winning choir school designed by the late Leo de Syllas of ACP, and the Ministry of Public Building and Works held an architectural exhibition at the Building Centre and topped out a radio tower at Birmingham. This is in concrete peg formation as opposed to the concrete kekab in London.
The enquiry on Stanstead Aerodrome was held and the inspector said he was tempted to close it because the Ministry of Aviation contradicted themselves on travelling time from London to Stanstead and a plaintiff QC said the Ministry's case had been 'badly prepared and is a shabby and inadequate job'. Another speaker said if Stanstead became London Airport 3, US air base Weathersfield must close. The US Air Force said Weathersfield was a NATO base and could not be closed unilaterally by either US or UK (another job for Mr Wilson?). In the meantime *The Observer* was plugging to turn the Island of Sheppey into a monster airport to replace Heathrow and Gatwick; nine parish councils near Gatwick protested against its increased use, and the Gas Board announced they would be introducing Saharan natural gas to Canvey Island.
Mr Wilfred Andrews, Chairman of the Roads Campaign Council, pointed out with asperity that the USA is building 1000 miles of motorway in five months, whilst UK is taking 15 years over the same task. The Electrical Vehicle Association of Great Britain urged the adoption of electric cars for city centres, and Professor Buchanan produced a plan to preserve Bath and said, 'No attempt had been made to estimate the total cost'. However, battery manufacturers will be glad to learn that a need for small electric floats would be part of the project.
Mr Crossman, Minister of Housing and Local Government launched a nation-wide drive to increase building by industrialized methods to 100,000 houses a year by 1970, and the National Building Agency started issuing appraisal certificates for various industrial systems.
Promised delights for the New Year include a projected conference and building exhibition in September at Southport, Lancashire; a conference on the teaching of industrial design at Scarborough in April; a residential school in April at Manchester University to consider design procedure in architectural practice; and, of course, the RIBA Conference in Dublin in September.

Aalto for Florence
Alvar Aalto is to design a cultural centre for a new district in Florence. In the picture of the model of the district the X marks the spot.



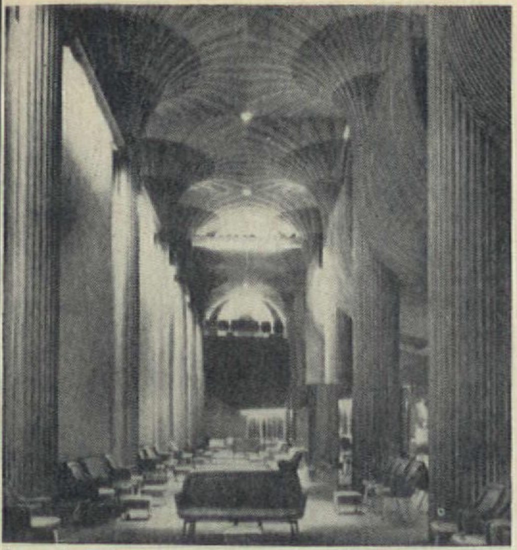
GLC Kidbrooke housing
The GLC Housing Committee have approved a layout for the first stage of the Kidbrooke comprehensive scheme in Greenwich, to provide 960 homes, two schools, shops etc.

Co-ordination of building dimensions
The history of dimensional co-ordination, and the ways in which the building industry should tackle the dimensional problems of designing and co-ordinating components are set out in a report, *The Co-ordination of Dimensions for Building*, by Bruce Martin, in collaboration with MOPBW. Available from the RIBA, price £1 15s.

Footnote to Thonet exhibition
Adolf Loos commenting on his own and Le Corbusier's choice of Thonet chairs commented that the latter had, unfortunately, chosen the wrong model. (See page 45.)

Culture at any price in Glasgow

A. G. Jury, City Architect and Planning Officer of Glasgow, was recently quoted as saying that 90 per cent of people do not notice what buildings are like. He was attempting a defence of his £4 million cultural centre design. The centre, incorporating a concert hall, civic theatre, repertory theatre, and art gallery, as well as extensive car parking and a 3½ acre 'plaza', had come under considerable fire from most, it seems, of the remaining 10 per cent.
For the past months the columns of *The Glasgow Herald* have intermittently carried letters, in the main critical, both of the Corporation's rejection of an architectural competition, and of the quality of the design now produced by the municipal team. Prominent in this criticism, fourteen professors of the Universities of Glasgow and Strathclyde have made a joint protest calling on the Corporation 'to have second thoughts' and advocating an international competition. Appeals have been made for the RIBA or the RIAS to examine and comment upon the design. National press coverage, obtained largely by the determined lobbying of the local architectural student body, comes significantly months late. Its effect is likely to be minimal since the provinces tend to see through criticism which compensates for its belatedness with unnecessary vitriol. Indeed the danger now is that reactionary heels will be dug in. It is fortunate that the immoderate outburst in *The Observer* has been preceded by sensible editorials in the Scottish press highlighting 'the vital consideration . . . that Scotland's greatest architectural opportunity should neither be lost nor seem to be lost'.
However, the local architectural profession remains silent. President of the Glasgow Institute of Architects, Mr Jack Coia, has stated that his hands are tied. Professional etiquette, it seems, precludes overt criticism. But 'Letters to the Editor' are not slow to point out the profession's dependence upon the City for a large slice of work. How far, one wonders, has this 'marsupial relationship' frustrated the integrity of informed professional opinion.
Meanwhile the furore continues. Is Mr Jury's scheme worthy of the occasion? Should the City abandon it in favour of an international competition? Is there a danger of a 'cultural ghetto'? Honour is now at stake and a retreat by either side will be difficult to achieve. Nevertheless, one is left with the feeling that there are many many Glaswegians who would rather have a decent house for their money than a £4 million cultural white elephant.



Lundy's cornucopiae

Victor Lundy's new shop for Singer is remarkable. It is another variation of that rilled and convoluted timber theme* that he exploited so conspicuously in 1961 for the I. Miller shoe store on the corner of 57th Street and 5th Avenue, New York. 'I had been thinking,' he wrote on that occasion, 'I wanted to do an abundant, wonderful thing. I wanted to make the women shopping for shoes feel like great ladies.' One can have no certainty of his relationship with I. Miller after the failure of that venture. The great ladies simply did not want to buy. There is no recorded censure or nasty comment. Other decorators succeeded Lundy at I. Miller. But Singer seem to have encouraged him to go the same uncommercial way again. Admittedly there is more glass than timber this time, more sight than obstruction, but clearly the merchandise is irrelevant to the fantasia of curving timber forms, mirrors and their myriad reflections of the spaces and shapes. It is a fantasia on success. But it is also the malady of a clever man.

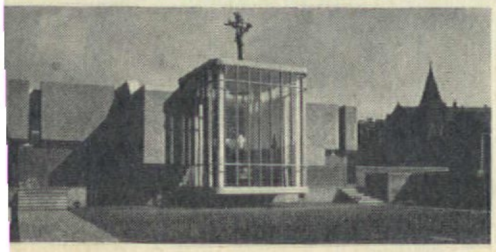
rchitecture Forms and Functions II, Interiors 8/1965

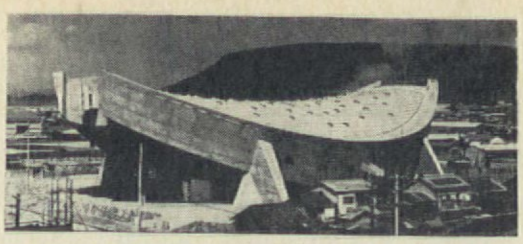
*But also interpreted on occasion, in concrete as in his IBM building at Cranford.

'Arch. d'Aujourd'hui Sept.–Nov. 1965

hurch in Leeds

erek Walker was the architect for the reinforced concrete RC Church of the Sacred Heart the centre of a new development area of eds. Shown here is the Baptistry, a glass rret at the main entrance to the church.

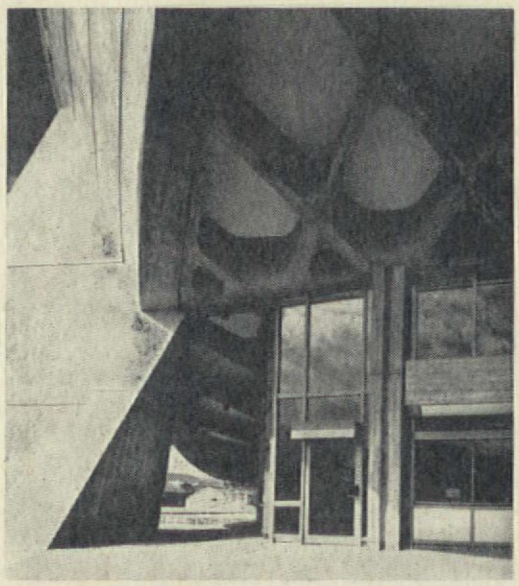


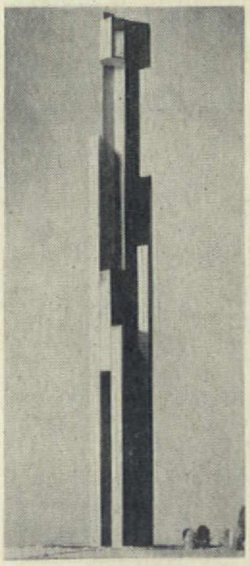


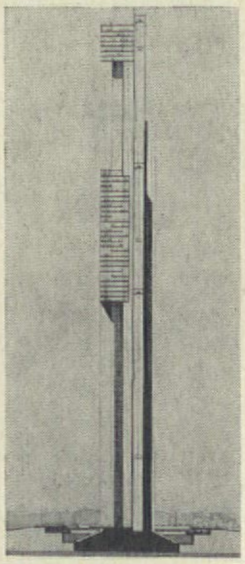
Tange at sculpture

Kenzo Tange's zealous pursuit of sculptural form for the Kagawa Prefectural Gymnasium has made it look rather like an ornamental urn offered in the name of Architecture; but there is a more robust and vigorous strain to this method of design, a hybrid, strongly Corbusian, yet adapting itself to dubious Japanese dreams. And adapting itself while retaining particular Japanese qualities. I am referring to the firm Japanese control of scale. The door knobs and doors, the corridors and changing rooms, all relate to the massive scale of the gymnasium itself and its cyclopean structure. The building is a unit. Though Tange's feeling for significant form may have its dubious side, its source is in Japanese history and architectural tradition, and is still able to affect us powerfully.

Japan Architect August 1965

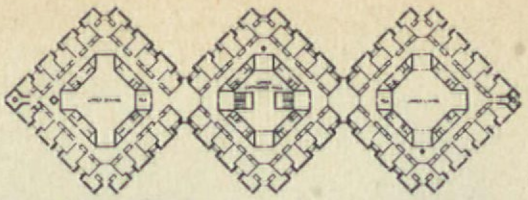






High tower

A study by Alberto Rosselli for a building (400m high), probably for TV, but primarily intended as an attempt to relate buildings of different function together in a unified mass, that will be in scale with modern motorways.



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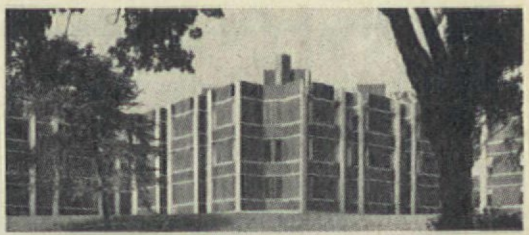

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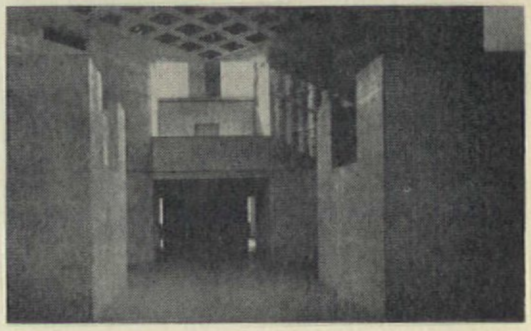

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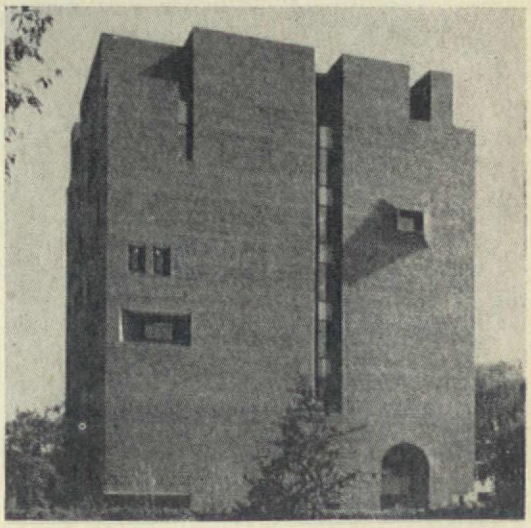
Castles in USA

With so many magnificent medieval castles to choose from, recent American efforts to conjure up the 'castle air' are oddly uninspired. Better to have imported the originals as of old. Louis Kahn's well-known design for the Bryn Mawr College dormitory **3**, **4**, **5**, now completed, appears as the realization, in concrete—with a veneer of black slate—of one of John Thorpe's silly, symbolic houses rather than the massive foursquare keep that was sketched some years ago. Indeed the whole now has the jaded air of an Elizabethan conceit; the more so when studied in conjunction with Kahn's portentious statements of intent. Entering a square at its corner (an explanation of the plan form) produces a 'delight in discovering nature'. The crust of bedrooms surrounding the three cores is 'a molecular structure that looks for light'. A web of words is spun to ensnare the knight's errant who dare to enter there.

Forum November 1965, *Fortune* December 1965

But even more pedestrian in its borrowing from the past—the recent past included—is the Roy E. Larsen Hall at Harvard University **6**, intended for graduate teaching. The sheer brick walls are slit and facetted. The fenestration is artful and the floor levels are delicately marked by the spandrels spanning the clefts—lip service, presumably, to functionalism.

Architectural Record November 1965, *Progressive Architecture* November 1965



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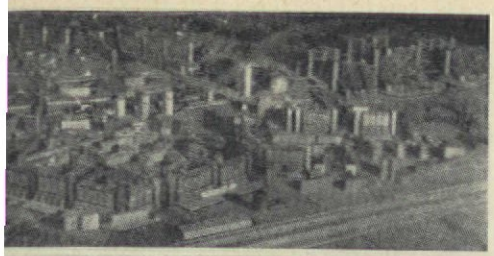
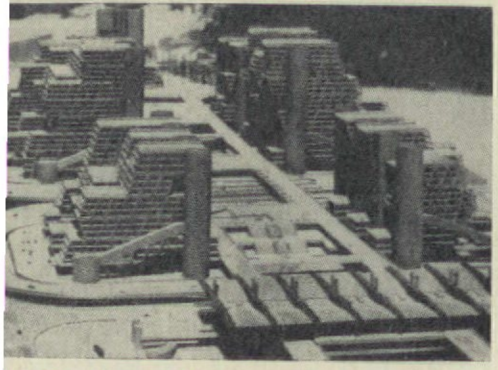


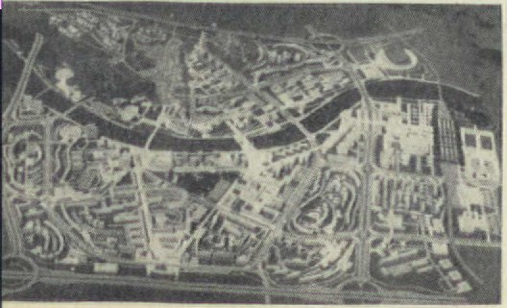


kopje planned

ıe magnanimous and humane UNESCO-ɔonsored competition for the replanning of ιopje has resulted in a compromise that is ely to erode all forceful and comprehensive lution. Eight firms were invited to compete, ur town planning institutions in Yugoslavia, ɛnzo Tange from Japan, Luigi Piccinate from ıly, Maurice Rotival from the USA and van ɜn Broek and Bakema from the Netherlands. ıe international jury (Arthur Ling representing e UK) has been unable to choose a single m to pursue the development. Tange has ɜen given 60 per cent of the votes, which akes him nominally the winner, but confers ı him no real authority. The Town Planning stitute of Zagreb was awarded 30 per cent of e votes. But, in addition, the jury made a ımber of recommendations of its own.

ange's design **1, 2**, relates not only to his ɔkyo plan (*AD*, October 1964) but also to ozaki's independently developed spatial city *D*, October 1964). The Tange design was ɜverely critized for its large out-of-scale ructures, a comment that is little inspiring of ɔnfidence in the jury's appreciation of the ɔntrolled scale of the whole development roposed. Certainly their alternative choice has ttle enough scale—in or out—and perpetuates ıe incoherent sprawl of the town before the arthquake. The only part worth retaining, the urkish quarter, would sit far more happily ithin Tange's urban structure than in the rtistic mess of buildings shown in the Zagreb ıodel **3**. But the Zagreb design has the virtue f what the jury call flexibility, and probably ιkes more carefully into account that under-round network of sewers and cables that have urvived the disaster and require to be used, hich means that it is eventually most likely to e accepted as the official favourite. No master-ıl solution seems now possible—if indeed it ver is in an existing city.

rogressive Architecture November 1965



Factory aesthetics

To those architects who hold tenaciously to the tenets of functionalism, plant and factory installations are an especially provoking challenge. The functions can be more clearly stated than in most other buildings. And the functions are for the most part mechanical. Their expression can be clear cut and unequivocal. Yet—with Poelsig and Gropius perhaps as honourable exceptions—no architect in the twentieth century has designed a factory with even a hint of that satisfying, direct expression of function that we enjoy in every petrol refinery. The *International Asbestos Cement Review AC 40* offers a range of no less than twenty-four recent plant and factory designs that confirm this sad conclusion. There are good things, even when the organization of the factory calls for nothing more than a vast expanse of roofed area. But in each case the felicities of the artist have softened the architectural edge. Invariably applied lettering is disastrous—both on John Parkin and Associates' salt mill outside Ontario **4** and Kurt Ackermann's cement works at Harburg, Germany **5**. Even Riccardo Morandi's power station at Livorno (illustrated also in *L'architettura 120*) has, somewhere, been devitalized. Only at the level of the direct expression of organization—does architecture arise from these buildings and then, instead of being heightened by architectural expression, it is smothered.

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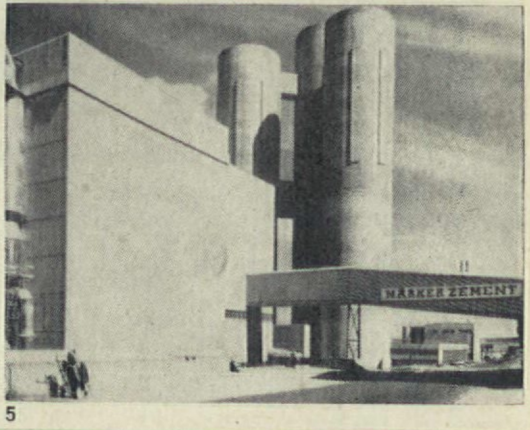

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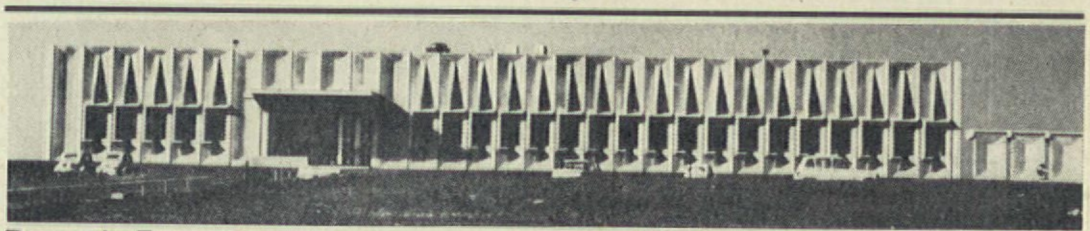
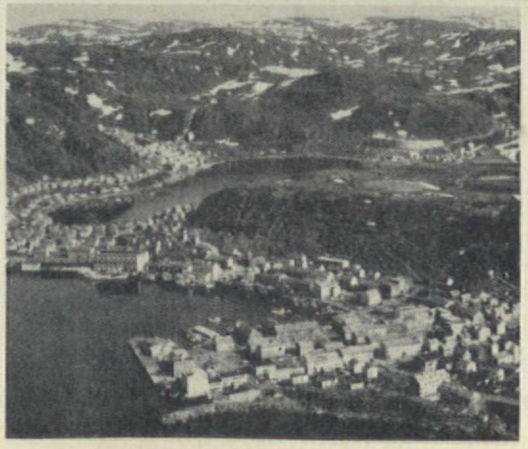


Breuer in Europe again

Marcel Breuer has built in Europe again. This time forty kilometres outside Brussels for the Société Torrington, manufacturers of fans and machinery. The bleak uninteresting site might seem to have called for a building of more lively play than usual, but the non-loadbearing precast panels with which the façade of the factory is decorated partake of the realm of exhibition sculpture rather than industrial building and prompts one to repeat once again I. Chippendale's bleat 'What happened to baby Breuer?'

Techniques et Architecture, July, 1965



Suburb in a building

Hammerfest, the northern-most town in the world, has been extended on its southern boundaries by the addition of one grandly conceived and meticulously styled block of flats, designed by Astrup and Hellern of Oslo. There are almost 150 new living units, yet the sprawl of the town has in no way extended and the openness and the scale of the countryside have even been reinforced. The tact and consideration of the designers has virtually no parallel amongst either the speculators or the solemn town planners who are busy developing the suburbs of Britain.

Bauwelt 2 August 1965


One of the really good things about today's way of life is the shower. The exhilarating, refreshing shower, now universally demanded by the modern family. But the shower isn't what it was. It has developed, matured, grown up. No more temperament, no more blow hot—blow cold. And all because of the Leonard thermostatic control—a strict disciplinarian if there ever was one. With the utmost precision, Leonard selects temperature and flow. And never wavers. Brings modern shower luxury to everyone—simply, precisely, unfailingly. Are *you* shower-minded?
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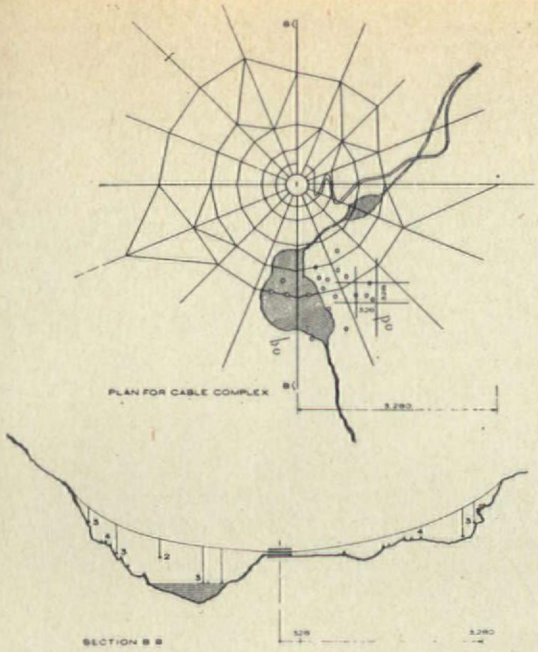

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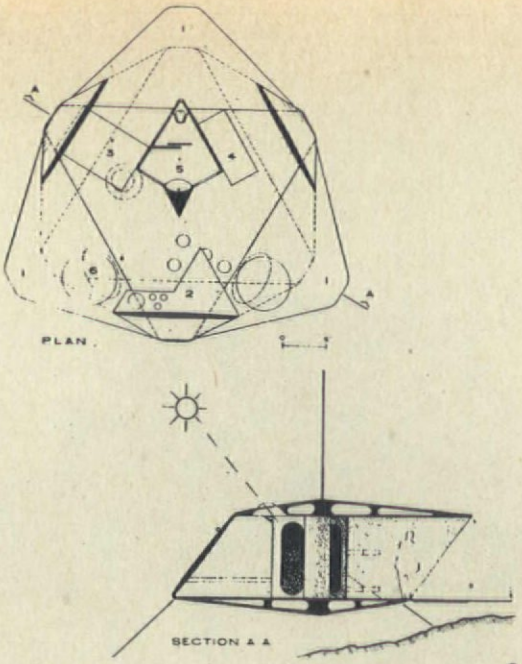

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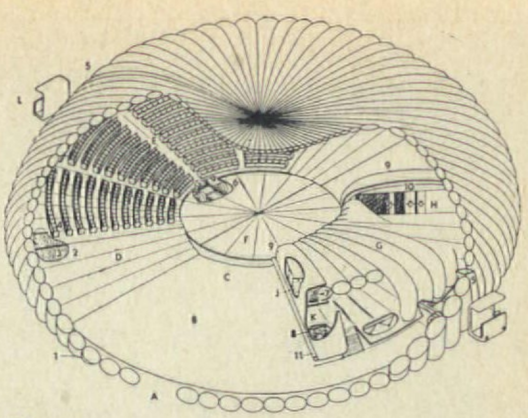

Blow-up

Willi Ramstein has published another of his elegant, carefully considered designs—an inflatable theatre. The whole is made up of inflated ribs of nylon supporting not only the outer envelope, but the galleries surrounding the circular stage.
L'Architecture d'Aujourd'hui June–July 1965.

Spiderweb city

Guy Rottier has opted for total mobility. His helicopter holiday house, designed in association with Charles Barberis (see *AD*, January 1965), has been succeeded by another demonstration of unfettered, escapist living. A series of towns in the Alps or strung out along the Mediterranean coast for holiday dwellers, consisting only of cables. Each cluster **1**, covering 750 acres, is made up of a network of cables arranged somewhat like a spider's web, and from this network dangle myriad cabins **2** that can be raised or lowered, or detached altogether to float on the lakes or to rest on their own extendable legs on the rocks. An organization problem is the different rate of movement required by each cabin dweller—the intention is that on the radial lines the cabins will be compelled to move, on the concentric cables they may come to rest.
Progressive Architecture November 1965

In Cologne, a less ambitious, though no more prosaic attempt to develop the cable car theme has been made by Gerd Lohmers, who has suggested a bridge of cable cars to link the Zoo with the Rhine park on the other side of the river. There is even a likelihood that this might be built.
Bauwelt 6 December 1965

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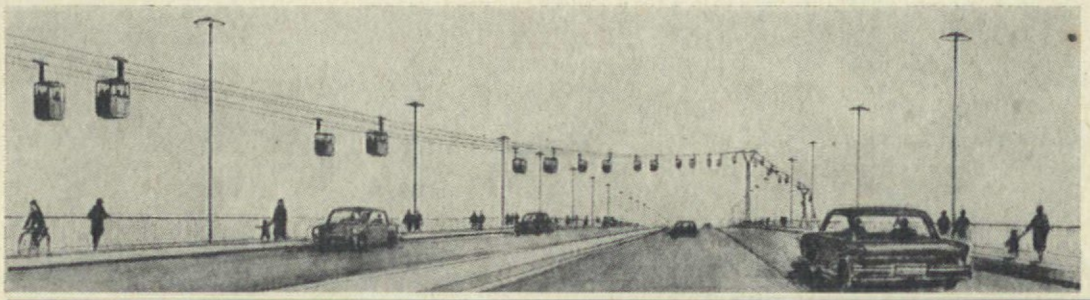


BASA Conference

A 'Chumbley' second cousin to the 'Daleks', fugitive from BBC Television's *Doctor Who* stood sentinel at the door. Girls in black fish-net stockings and red T-shirts bearing the words ARCHIGRAM strategically across them, distributed handfuls of literature to an audience of 300 students from most of the major architectural schools in the country, pop-music blared. This then was the BASA Conference, held at the Building Exhibition at Olympia last year, and holding court, fresh from their wildly successful take-over of the RIBA when an audience of 350 students crowded the building, were the grand prophets of the future from the architectural world, the ARCHIGRAM GROUP. Lights were dimmed and the audience subjected to a three-quarter hour non-stop bombardment of 'visual goodies' from a battery of equipment at the back of the hall. Coloured slides projected images of space capsules, computers, underwater hardware, girls in the latest Courrège gear, pop- and op-art, the group's own space age architecture, and films of 'Man in Space' and 'Robots' were simultaneously thrown on to three giant screens to the accompaniment of electric sounds, TV commercials, modern jazz and pop.

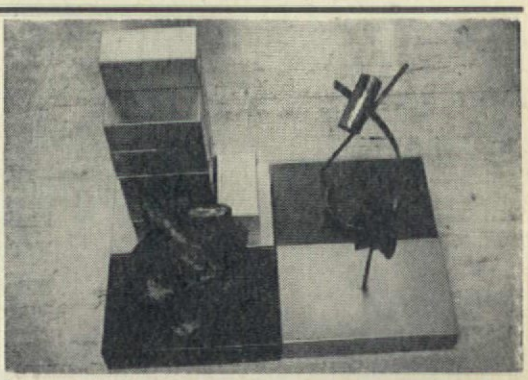
Hudson and Setch

Jasia Reichardt

The notion that form, colour, tone and sound are directly analogous to feeling is an assumption that has been widely upheld by some critics. One could not quarrel with the application of such an interpretation to certain type of paintings, e.g. those that are specifically romantic or expressionist, but it would be unthinkable to comment on works in the idioms of construction and assemblage through such criteria. The imagery, forms and colours, tones and textures in the work of Tom Hudson and Terry Setch, for instance, often contradict the very feelings they should represent. The images speak through loaded associations of banal ready-mades, ambiguity of content, ambiguity of form and mechanical finish.

Terry Setch's wallscapes, gnomes and figures **1** relate to the horror of stylization as opposed to style, the paradox of taste, and the possibility of transforming those symbols of class—the artifacts—into elements of an extraordinary game, where no values remain intact. The banality of his fluted coloured columns with plastic at its most unpleasant, achieve the sort of transformation which through being completely marginal is all the more unexpected. The sort of irrational element that can turn the singing garage mechanic of the film *Les Parapluies de Cherbourg* into a plausible hero could endow Brighton rock, garden gnomes and plastic flowers in the hands of Terry Setch, with a certain type of magic.

Tom Hudson **2** works in greater variety of media. Many of his objects relate to charts which plot the progress of related images that at one extreme are completely mechanical, and at the other tend towards the organic. The imagery here is as ambiguous as the process. Hudson works in polyester, glass fibre, metals and perspex. The images are embedded in plastic in such a way that one has the impression of depth, space and perspective, whereas the surface is totally flat. His kit constructions and objects are parodies of taste, ironic comments on national emblems and digs at the symbols of contemporary culture. His overt use of forms which one encounters more often in relation to electrical apparatus than art objects, makes one think of industrial equipment as yet another inspirational channel for artists to explore. So far, assemblage has implied the use of discarded and broken furniture as well as other artifacts. For artists to draw on industrial forms as a visual language opens up completely different possibilities. The Hudson/Setch exhibition indicates some of the implications.



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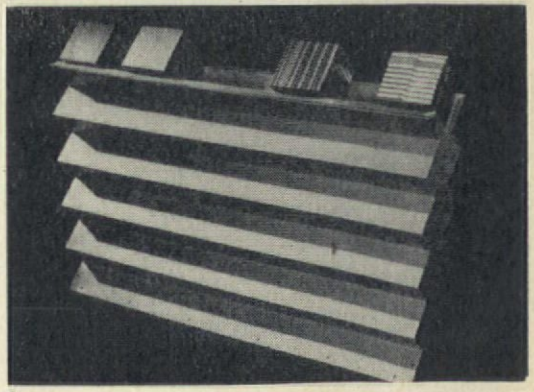


2

Around Britain 1

York and Leeds

Kenneth Appelby

Towards the end of last year Dr Patrick Nuttgens, the director of the York Institute of Advanced Architectural Studies, gelled a dismay wide-spread throughout York at the effects of buildings and planning policies seemingly unable to preserve the past or come to civilized terms with the present. He resigned from the local Architects' Advisory Panel.

Dr. Nuttgens' resignation caused the formation of two specific groups: one designed to press for more publicity about building proposals; the other, a student body, which organized a series of public lectures on the theme of planning and cities generally.

Later in the year, Labour lost control of the finely balanced City Council to a Conservative administration, now making an effort to get its policies across by some public discussion. A code for central area developers is being considered.

Simply, York's problem is a failure at Council level to formulate a policy on which any plan can be based, either by an outside consultant, as demanded by many people, or by the City's own officers: a failure to define York's role in modern England. This is coupled with a failure by the Chief Engineer and Planning Officer to convince people that his office could develop any such policy in a sensitive fashion.

This, though, could all be seen as part of the past, when the Development Plan is finally published. Already there are suggestions to close part of the central area to traffic at certain times, and a very real sign of change is the City Architect's scheme for the Nunnery Lane site immediately outside the City walls; shops and medium density housing using a deck to give total cars/people separation, though this complex again is severed from the walls by a four-lane carriageway.

In July, the Civic and Rowntree Trusts combined to sponsor a river scheme for the Ouse at York—designer H. F. Clarke.

The good Doctor's trumpet also roused the members of the virtually moribund end of the local society—shared with Hull—who not only called for a clear and unequivocal statement to be given on planning matters by their officers, but formed themselves into a new Chapter, now busy appraising its position and function within the York community; a far from easy job in a city where architecture can easily become confused with preservation and where the Civic Trust, vigorous in defence of the old, can attack the only modern building that tried to agree with it.

Hartry, Grover and Halter's Stonebow House **1**, ground and mezzanine shops with small office tower, all in very forcefully expressed concrete, shows in its interwoven spaces and levels just the kind of thinking York needs to carry its medieval streetscape into the twentieth century. If the building fails it does so not on the texture of its much-criticized concrete but because it is allowed to relate to so little else: only an overall, sensitive plan can get the City full benefit from architects who contribute at this level.

The growing University continues to dominate the built scene with both the CLASP-based buildings (see *AD* Dec. 65, p. 582), and Fielden and Mawson's successfully modern adaptations of existing and really very old buildings out at Heslington and in the City centre, where generally the uninspired nature of the new work, mainly office blocks and supermarts, is made more apparent by the quality of their surroundings.

Happily though, in George Pace, York has an outstanding man with an international practice, specializing, perhaps unfortunately for the City, in church work.

On the edge of the West Yorkshire conurbation and securely meshed into the future motorway system, Leeds seems a natural for a regional capital. And what is potentially the most interesting development within the area suggests the City is thinking at this level by creating a special committee of all the chief officers concerned with the traffic/environment problem; now linked with a group from the Ministry of Transport in trying particularly to beat the peak hour problem. In this context, the recent failure of the park-and-ride scheme is not taken too seriously; success was felt only reasonable within a fully integrated traffic scheme. (Only a daily handful swapped cars for a fast express bus to the centre.) Within the central area a one-way system designed partially to discourage through traffic makes the wide streets extremely hazardous and unpleasant; but the inner ring road, at present under construction, is the first major part of a policy eventually to separate cars and people within most of the centre—initially, by the partial closure of certain streets (linking the markets and arcades which are such a feature of shopping in Leeds) and eventually by a series of bridge decks and subways. Some buildings now under construction are designed to accept these decks, and certain of the subway connections have been started—one to link the new Merrion Centre into the existing shopping area.

Merrion Centre **2**—architects Gillinson and Barnett—combines cinema, bowling alley, offices, market, shops and multi-storey car park in a complex, fussy from a distance, but happier in the shopping mall where the bridges and the proximity of the units help bind the commercial display into a pleasant atmosphere for the pedestrian. Mosaic, the stock answer to the Leeds atmosphere, is in liberal evidence, though the car park, visually the most successful part, uses precast panels with a huge exposed aggregate.

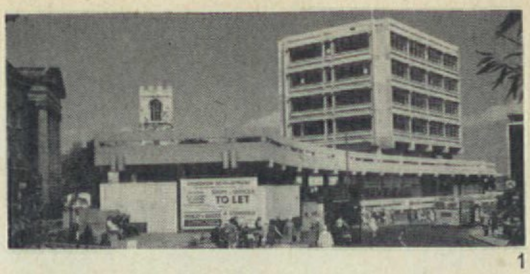
In contrast with the Merrion, Seacroft Centre **5** on the outskirts of the City is more satisfying architecturally, but not perhaps such fun to be with. Linking an existing village green with the new road system, the Centre is a civic development designed to serve a population of 85,000 with shops, offices, market, the ubiquitous bowling, etc.: fully integrated parking taken right into the gut of the place, and contours cleverly used to avoid any cut-off feeling at the higher shopping level. Architects G. Alan Burnett and Partners in association with the Leeds City Architect's Department.

At present reconciled to poor working conditions by the hope of brand-new accommodation, the Leeds Department, closely associated with the traffic/environment committee, are trying to give long-term valuation to the effects on building of a high-image public transport system; rapid mass transit between the central precincts and nodal points on the periphery. This is related with attempts to keep the individuality of existing settlements on the outskirts by selective development. At Bramley, due to start next year, they are using a deck access system **4** originated by the Yorkshire Development Group, itself based in the department, and which permits the use of a variety of materials within basic structure/planning constraints.

Part of the City core, the University continues to implement Chamberlin, Powell and Bon's master plan with more imaginative buildings than most in the centre. Jovially backing on to a cemetery the Henry Price hall of residence manages to echo the surrounding red-brick terraces and, in its podium wall—rough local stone—real, aboriginal Leeds.

North East Region's S. Hardy has taken a clean grip of a difficult problem at the new and still building City Station **6**, and across the road in City Square, Kitson, Pyman and Partners have just started one of the buildings designed to receive first floor decks; a promisingly simple 19-storey tower. Again lots of mozaic.

The seminal Leeds building though, the one which most successfully comes to terms with the place, is Yorke, Rosenberg and Mardell's small office and showroom for Kidds **3** (the Ryman Group). Perhaps not so effective as it should be because of an off-centre position, and in spite of errors of detail—the window cills are flat!—the precise engineering brickwork is entirely within the Leeds venacular.



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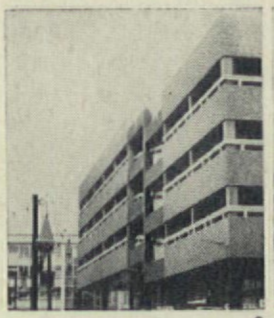

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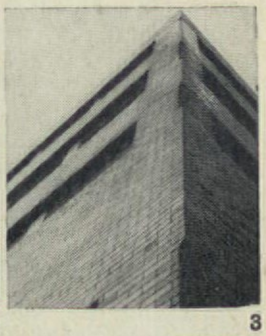

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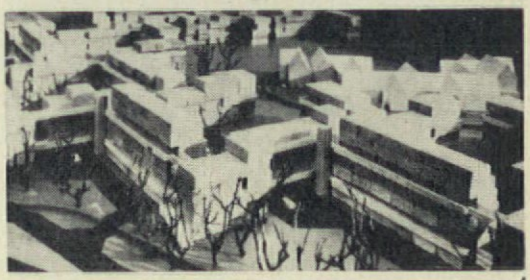

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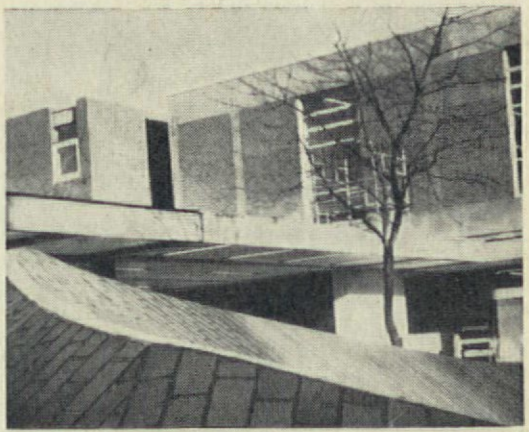

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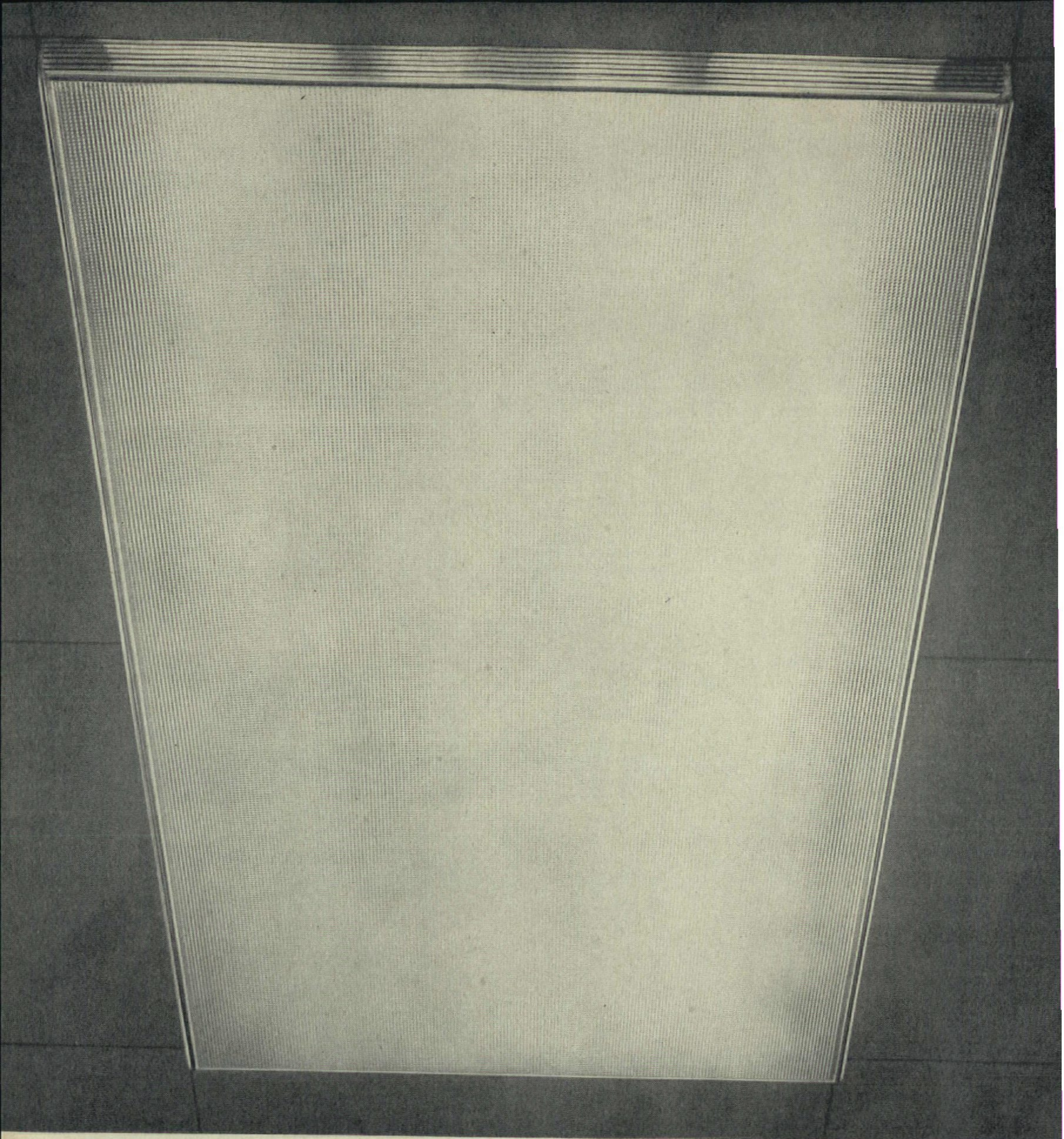

Dans ce numéro

Structures tridimensionnelles

Page 10

Bien des architectes renommés ont émis l'opinion que nous étions à l'aube d'une grande révolution architecturale, marquant un changement des structures bi-dimentionnelles du passé aux systèmes d'espaces tri-dimensionnels actuels et futurs.

Les charpentes ouvertes ont fair une grande impression sur l'architecture moderne et il y a bien des raisons pour expliquer pourquoi ces structures sont de plus en plus acceptées parmi les architectes.

Les architectes prétendent que ces structures leur donnent plus de liberté en leur offrant une plus grande diversité de formes expressives.

Les ingénieurs apprécient les avantages structuraux de ces charpentes, la légèreté qui leur est propre en même temps qu'une grande rigidité.

La grande rigidité de ces charpentes leur permet une plus grande flexibilité de tracé ainsi qu'une plus grande variation de l'emplacement des supports par rapport aux systèmes conventionnels.

Ces charpentes ont une réserve interne de force qui permet à la structure de supporter une surcharge localisée. Il est bien connu que même sous des charges asymétriques, la distribution de la tension dans les structures ouvertes est remarquablement régulière. Des charges concentrées peuvent être réparties plus facilement qu'avec les formes conventionnelles à cause de la distribution dans tous les sens de la tension.

L'expérience a prouvé, qu'en plus les structures ouvertes, même lorsqu'elles sont endommagées ne s'écroulent pas soudainement, elles commencent par fléchir, cette caractéristique est de grande importance en cas d'incendie.

L'accent mis sur la pré-fabrication ces dernières années, a attiré l'attention des architectes sur le fait que les charpentes tridimensionelles peuvent être construites à partir de simples unitées préfabriquées qui sont dans la plupart des cas de tailles et de formes standards. De telles unités produites en série en usines peuvent être assemblées aisément et rapidement sur place par une main d'œuvre à demi qualifiée. En même temps la petitesse des unités simplifient les problèmes de la manutention et du transport.

Les obstacles les plus importants qui en empêchaient l'utilisation universelle par le passé étaient la complexité de l'analyse de la distribution de la tension et la difficulté de joindre plusieurs membres en espace à des angles différents.

On vient maintenant à bout de ces difficultés. En général les structures ouvertes sont très difficile à déterminer et leur analyse par des méthodes rigoureuses a imposé par le passé des calculs longs et ennuyeux.

L'avènement du calculateur électronique a changé tout le procédé. Maintenant pour la première fois dans l'histoire du génie civil il est possible de s'attaquer aux analyses structurales même les plus compliquées avec une plus grande précision qu'auparavant et en moins de temps.

L'utilisation de la soudure a grandement influencé l'adoption plus générale des structures tridimensionelles en acier; les techniques modernes de préfabrication ont progressé et la standardisation des parties composantes à amené une réduction des frais et une simplification de l'érection.

L'intérêt grandissant envers les structures tridimensionelles peut être attribué, en partie, aux développements et à la popularité des structures en béton armé. L'élégance des formes obtenues grâce aux charpentes en béton armé a grandement attiré les architectes. Car la flexibilité et la facilité de formation du béton ont rendu possible la construction de n'importe quelle forme désirée. Malheureusement ils se sont aperçus que ces systèmes sont plutôt coûteux à cause de la nécessité d'avoir une charpente compliquée.

Les architectes se sont rendus compte qu'il était plus économique de construire des charpentes tridimensionelles consolidées en acier, en aluminium, en bois et en plastique plutôt qu'en béton.

Le nombre croissant de structures en acier et en aluminium construites dans les divers pays du globe indique clairement que l'élan de ce développement grandit si bien que l'on peut s'attendre à ce que l'on attache une plus grande importance à l'avenir aux structures tridimensionnelles.

Cet article a pour but de donner un aperçu des développements dans le domaine des structures tridimensionelles ces dernières années. De grands progrès ont été faits dans trois domaines, surtout du point de vue construction préfabriquée;

Des grilles à double couches,
Des voûtes cylindriques renforcées,
Des dômes renforcés.

Structures en plastique

Page 35

Des progrès considérables ont été faits dans les applications structurales en plastique. Au contraire des matériaux conventionnels, le plastique offre la caractéristique inhabituelle de comprendre plusieurs propriétés désirables en même temps, c'est-à-dire, légèreté, solidité, translucidité et résistance à la corrosion. Sa solidité par rapport à son poids dépasse celle de la plupart des métaux. Sa résistance à la corrosion et à l'usure est étonnante. L'aise à laquelle on le forme le rend très adaptable à la production en série et aux méthodes en chaîne des usines. Si l'on ne l'utilise que pour remplacer d'autres matériaux, le plastique peut être coûteux, mais si on l'utilise intelligemment en formes appropriées à ses caractéristiques, les propriétés uniques du plastique conduisent à des solutions très efficaces et économiques. L'utilisation du plastique pour les structures développera des produits entièrement nouveaux dont les formes et les apparences différeront de manière appréciable de celles déjà acceptées par le grand public. Un facteur de limitation de la conception des structures en plastique est la rigidité plutôt que la solidité, mais le manque de rigidité du plastique peut être surmonté en choisissant la forme structurale appropriée.

Les structures à revêtement renforcé démontrent de façon convaincante que leur face est d'abord fonction de la géométrie de la structure, c'est-à-dire de la configuration des unités interconnectées et dépend jusqu'à un certain point des propriétés du matériau qui les compose.

Les structures à revêtement renforcé représentent un domaine de possibilités bien inexploré pour l'utilisation structurale du plastique. Bien des structures en plastique on été construites ces dernières années. Des recherches l'ont prouvé.

1. Il est possible de concevoir et de construire de larges structures en plastique qui rempliront leurs fonctions techniques de façon satisfaisante.
2. Les propriétés mécaniques du plastique peuvent être définies par les mêmes concepts techniques que ceux appliqués aux matériaux de construction standards.
3. La conception technique de structures en plastique peut être effectuée par les mêmes principes que ceux qui gouvernent les structures en matériaux de construction standards.

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Estructuras tri-dimensionales

Página 10

Muchos arquitectos eminentes han expresado la opinión de que estamos en la víspera de una gran revolución arquitectónica, marcando el cambio de las estructuras bi-dimensionales del pasado hacia los sistemas espaciales tri-dimensionales del presente y del futuro.

Las estructuras espaciales estan ejerciendo un impacto obvio sobre la arquitectura moderna y hay muchas razones para que las estructuras espaciales estén ganando rápidamente aceptación entre los diseñadores.

Los arquitectos claman que las estructuras espaciales les dan mayor libertad, proveyéndolos con formas más expresivas.

Los ingenieros civiles aprecian las ventajas estructurales de las estructuras espaciales, su liviandad inherente, combinada con una gran rigidez.

La gran rigidez de las estructuras espaciales permite una mayor flexibilidad en el trazado, hace posible mas variación en la ubicación de los apoyos que en los sistemas convencionales. Las estructuras espaciales tienen una reserva de resistencia en sí mismas permitiendo a una estructura absorber sobrecargas locales. Es bien sabido que aún bajo cargas asimétricas, la distribución de momentos en las estructuras espaciales es extraordinariamente pareja. Cargas concentradas pueden ser acomodadas más fácilmente que en las formas convencionales debido a la distribución multidireccional de los momentos.

La experiencia práctica muestra, que además, las estructuras espaciales, aún cuando duramente dañadas, nunca se derrumban repentinamente, pero empiezan a ceder; esta característica es de gran importancia en caso de incendio.

El énfasis puesto en la prefabricación durante los recientes años, ha llamado la atención de los diseñadores hacia el hecho de que las estructuras espaciales pueden ser construídas con unidades simples prefabricadas; en muchos casos de tipo y dimensiones normales y corrientes. Tales unidades, producidas en serie, en la fábrica, pueden ser fácilmente y rápidamente armadas en la obra por operarios semi especializados. Al mismo tiempo, el pequeño tamaño de las unidades simplifica los problemas de manejo y transporte.

Los principales obstáculos que en el pasado detuvieron el uso de las estructuras tri-dimensionales fueron la complejidad de los análisis de distribución de fuerzas y la dificultad de unir varios miembros en el espacio, a diferentes ángulos.

Estas dificultades estan siendo solucionadas. Las estructuras espaciales en general son muy indeterminadas, y su análisis por métodos exactos, ha conducido en el pasado, a cálculos tediosos y largos. La introducción del calculador electrónico ha cambiado todo el proceso. Ahora, por primera vez en la historia de la ingeniería civil, es posible enfrentar el análisis de las estructuras complejas, con una mayor exactitud que nunca antes fué posible y con una gran reducción en el tiempo empleado.

El uso de soldadura ha influenciado enormemente el presente mayor uso de estructuras espaciales en acero; técnicas modernas de prefabricación la han acelerado y la normalización de los componentes ha conducido a una reducción de los costos y a una ejecución simplificada.

El creciente interés por estructuras espaciales armadas, puede, en parte, ser atribuído al desarrollo y a la popularidad de las estructuras cáscara en concreto armado. La elegancia de las formas obtenibles con estas estructuras atrajó enormemente a los arquitectos. La flexibilidad y plasticidad del concreto lo hacen aparecer como capaz de dar cabida a toda forma. Desgraciadamente los arquitectos encontraron que tales sistemas eran muy costosos, debido principalmente a la necesidad de usar moldajes complicados.

Ahora se dan cuenta de que es posible construir estructuras espaciales armadas mas económicamente usando acero, aluminio, madera y plásticos en vez de concreto.

La creciente cantidad de estructuras espaciales en aluminio y acero construídas en varios países a través del mundo, claramente indica que el ímpetu de este progreso está todavía creciendo y que uno puede esperar un mayor uso de estructuras tri-dimensionales en el futuro.

Este artículo se intenta como un exámen del progreso, en el campo de las estructuras espaciales, durante los recientes años. Un gran desarrollo se ha alcanzado en tres campos:

trazados en doble plano
bóvedas de cañon armadas
cúpulas armadas

Estructuras espaciales en plástico

Página 35

Un considerable progreso se ha alcanzado en las aplicaciones estructurales de los plásticos. No como los materiales convencionales, los materiales plásticos exhiben la calidad poco usual de combinar varias propiedades ventajosas al mismo tiempo: por ejemplo; liviandad, resistencia, transparencia y su resistencia a la corrosión y al son considerables. Su adaptabilidad a las formas los hace muy útiles para los métodos de producción en serie y armado en la fábrica. Si son usados solamente como una alternativa a otros materiales, los plásticos pueden resultar siendo mas costosos, pero si son aplicados inteligentemente, en formas apropiadas a sus características, las propiedades únicas de los plásticos pueden conducir a soluciones altamente eficientes y económicas. El empleo de los plásticos en estructuras podría llegar a desarrollar productos enteramente nuevos, cuyas formas y apariencias podrían diferir apreciablemente de aquellas ya aceptadas por el público en general. El factor que limita el diseño de estructuras en plástico es la rigidez mas que la resistencia, pero la falta de rigidez en los plásticos puede ser solucionada efectivamente usando la forma estructural apropiada.

Las estructuras a base de superficies tensionadas pueden demostrar de una manera convincente que su resistencia es básicamente una función de la geometría de la estructura, v. gr. de la configuración de los elementos interconectados, y depende solamente y hasta cierto punto, de las propiedades de los materiales con los cuales han sido ejecutadas.

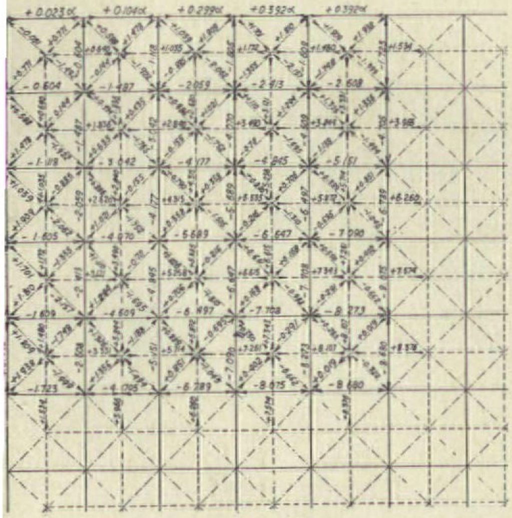
Las estructuras espaciales del tipo de superficies tensionadas forman un campo de posibilidades inexploradas para el uso estructural de los plásticos. Muchas estructuras espaciales experimentales en plástico han sido construídas durante la última década en varios países. Las investigaciones han probado que:

1. Es posible diseñar y construir grandes estructuras hechas con materiale plásticos los cuales ejecutaran sus funciones de una manera satisfactoria.
2. Las propiedades mecánicas de los materiales plásticos pueden ser obtenidas a través de los mismos principios de ingeniería que los aplicados a las estructuras hechas con materiales corrientes de construcción.
3. El diseño ingenieril de las estructuras hechas con materiales plásticos puede ser obtenido a través de los mismos principios de ingeniería que los aplicados a las estructuras hechas con materiales corrientes de construcción.

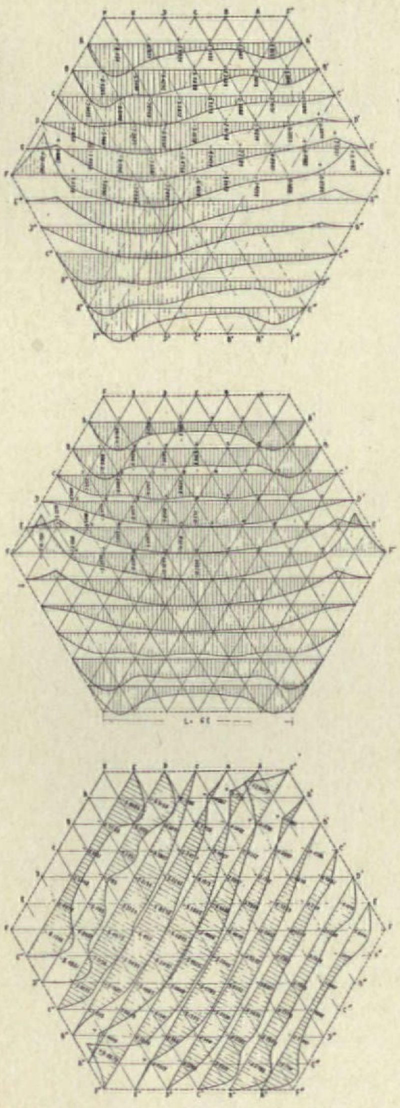
Space structures and the electronic computer

. S. Makowski

Diagrams show stress distribution in various types of space frames determined by electronic computer, all analysed at the Space Structures Research Centre, Battersea College of Technology.



Above: Loads in a double-layer grid 25m×25m under uniformly distributed loading



Above: Distribution of bending moments in a three-way grid of hexagonal layout under symmetrical and unsymmetrical loading

One of the reasons for the rapid acceptance of space frames and their general development within the last decade has been the introduction of electronic computers. The advantages of space structures were known to engineers for many years, but their analysis has been extremely tedious and time-consuming. Design in the past has been based on high factors of safety because of the many approximations and simplifications used in analysis and these approximations rarely lead to economical use of material.

The introduction of the electronic computer is now rapidly changing this picture. What is an electronic computer? What can it do? What is its effect upon civil engineering? Will it influence the work of architects? These are some of the questions which are being currently asked.

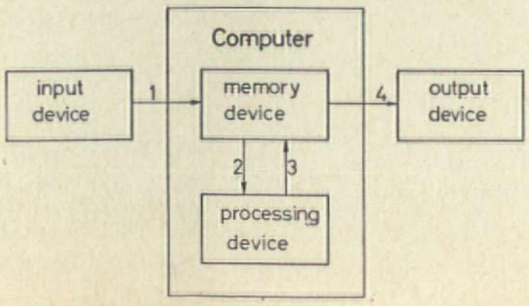
The information which is being given about computers is profuse and the technical terms and the jargon used by those concerned with computers does not help to make their purpose and significance clear. Programming, flow diagrams, floating point number, binary digits input, output, print-out, sub-routines, autocode, etc.—all these words have a meaning for the people using a computer, but they remain largely incomprehensible to the general public. From all the developments that have taken place in civil engineering in the last decade, the most important one has been the introduction of electronic computers. Their impact is now being felt by all engineers, even if some of them still do not fully understand the revolutionary nature of this development.

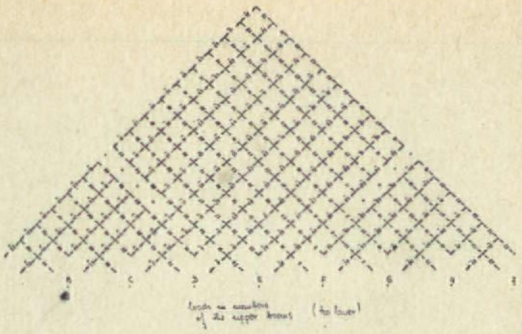
It can be stated, without any fear of contradiction, that the electronic computer is the most important tool put in the hands of the designer. The computer is a high-speed calculating device which produces enormous saving in man-hours and engineering cost, when carrying out complex calculations.

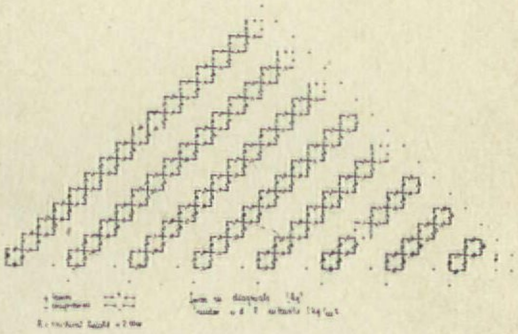
With the use of the computer, engineers are now able to tackle problems which were previously beyond their reach and incapable of solution with available tools. The electronic digital computer which is really a numerical calculator is probably the most useful kind of machine for structural calculations. One should not consider the digital computer as merely an overgrown rapid desk calculator. It is more than that. It is able to store information, follow predetermined processes and produce a written answer but only when it is given a programme of work to do. This programme has to be devised, but many general programmes can be used so that the application of the machine can often be quite easy. The computer is exerting great impact upon the whole philosophy and basic concepts of analysis and design of structures.

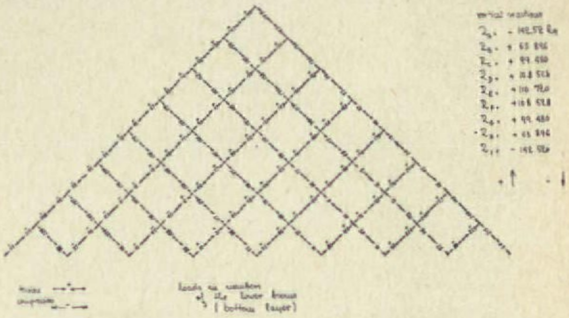
Because of the ease with which stresses can be calculated in complex systems, designers now no longer hesitate to explore new ideas, new shapes and new forms. The designer has now time to check various alternative schemes and to compare their merits.

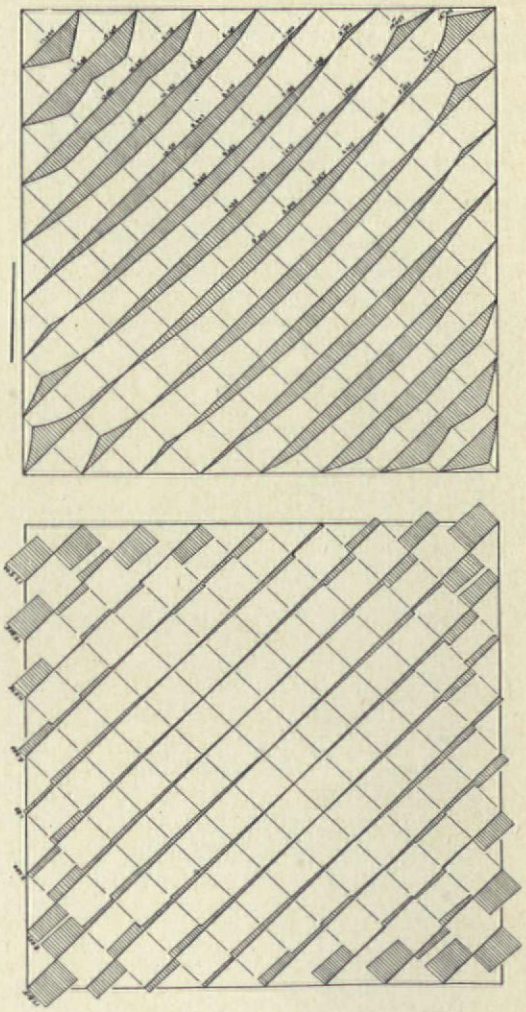
The basic concept of the computer is simple, although the actual operation of the electronic computer circuits may be very involved. Essentially a computer is an information processing machine and consists of the four devices below.







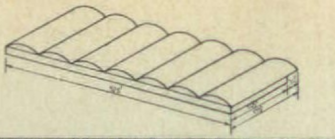


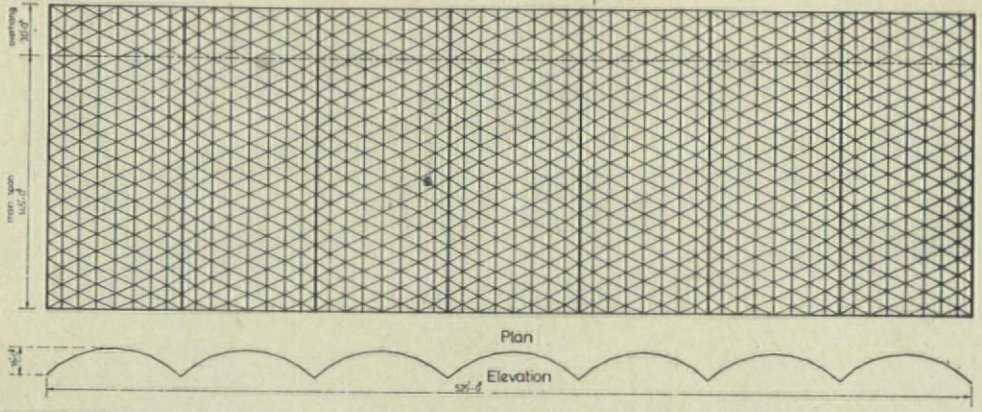


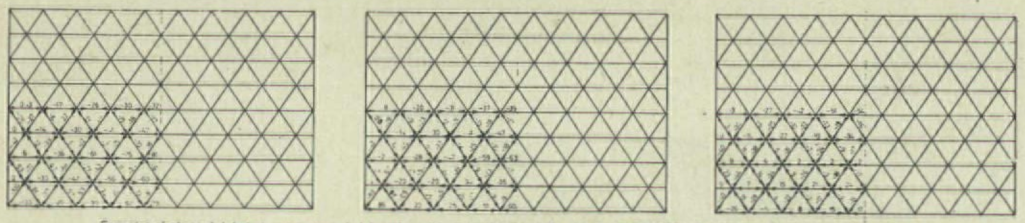
Above: Forces in the bars of the roof grid covering one of the pavilions of the French exhibition at Nancy, built in 1964

Example of the three way tubular barrel vaults to be erected for the Port of London Authority.
Consulting Engineers: Messrs Harris and Sutherland London

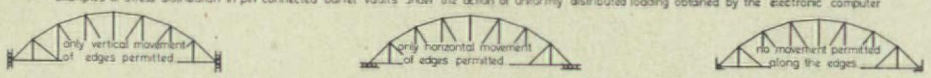
Structural analysis of the barrel vaults carried out by:
Space Structures Research Centre
Department of Civil Engineering
Battersea College of Technology
London







Examples of stress distribution in pin connected barrel vaults under the action of uniformly distributed loading obtained by the electronic computer



three examples showing the influence of boundary conditions upon the stress distribution

A very important part of the computer is the 'memory' device in which coded information is stored. The external communication enters the computer through the 'input' into the 'memory' device, gets processed, i.e. performs certain simple arithmetic or logical operations and leaves the computer as the 'answer' through the output device.

Although a computer is often used to speed up or improve engineering calculations, the main difference between a high-speed desk calculator and an electronic computer lies in the ability of the digital computers to deal with general programmes.

The preparation of a typical computer programme consists of the following seven parts:

programme planning—this step comprises the definition of the problem, general method of analysis, determination of the basic assumptions and limitations of the method.

analysis—the method of analysis is specified, parameters considered and the numerical techniques determined to obtain these parameters.

programming—preparation of the flow diagram and the specification for dealing with many alternatives.

coding—translation of the procedure into a language acceptable to the computer.

checking—of the programme.

documentation—in the case of important programmes used frequently by other operators, it is usual to prepare a detailed description or manual.

production—the actual use of the programme and the production of the required results. The above description refers to the preparation of a special purpose programme, which may be included in the programme library for frequent use.

During recent years several general programmes have been prepared for the analysis of space structures. In skeletal space frames the primary stresses are usually calculated on the assumption that members are pin-connected at their ends and carry axial forces only.

In certain types of space structures, especially single-layer braced barrel vaults, this has to be corrected by the superposition of secondary stresses produced by the rigidity of connections. In double-layer grid frameworks the secondary stresses prove, as a rule, to be small and are frequently neglected altogether.

For smaller space structures, conventional methods of analysis may be used, e.g. the tension coefficients approach. For large and highly redundant space frames, the conventional methods of analysis become rather tedious, as they result in systems with a large number of simultaneous equations. However, if a standard computer programme is used and the number of equations is very large, then there might be difficulty in storing and manipulating the data, and as a result computers with very large storage capacity are required.

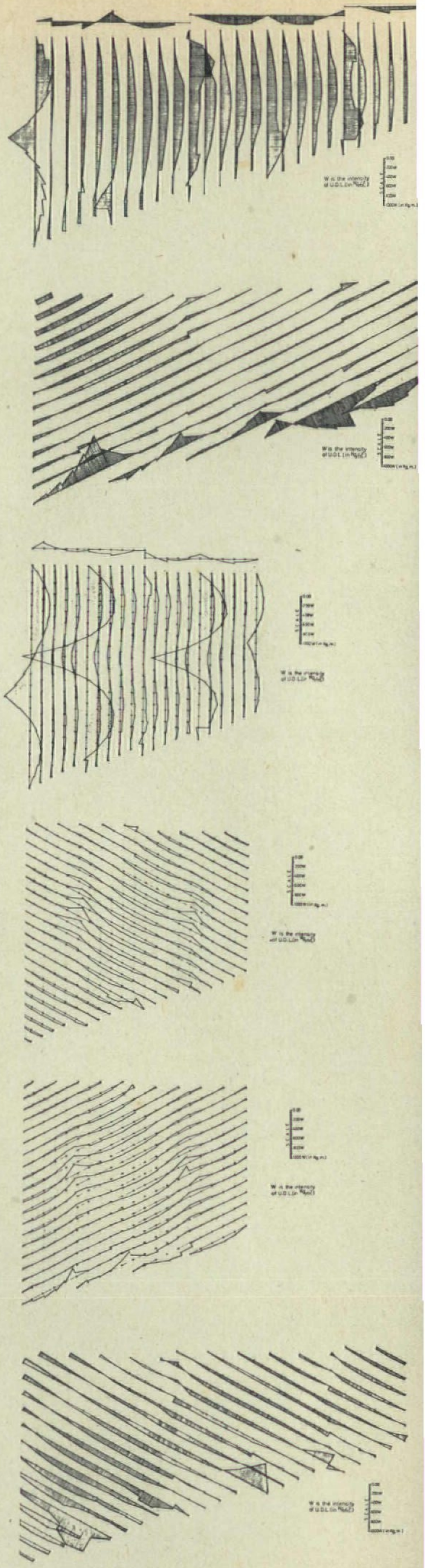
Another difficulty when dealing with a large number of simultaneous equations is the accumulated rounding error and the length of the computation time which is porportional to the cube of the number of equations. Various techniques in programming have been developed when dealing with highly redundant space frames.

Space structures of the skeleton type can be easily divided with a number of interconnected parts. This means that matrix partitioning can be used to separate the overall problem into a number of smaller ones whose solutions are also interconnected.

Several techniques in such 'step-by-step' methods have recently been developed.

Basically the approach consists of the determination of the flexibility of a small part of the structure and then the addition to the first part of the remainder of the frame, joint by joint, calculating the change in the flexibility at each step. This procedure of adding joints has the advantage that no alteration in the previously calculated influence coefficients is necessary.

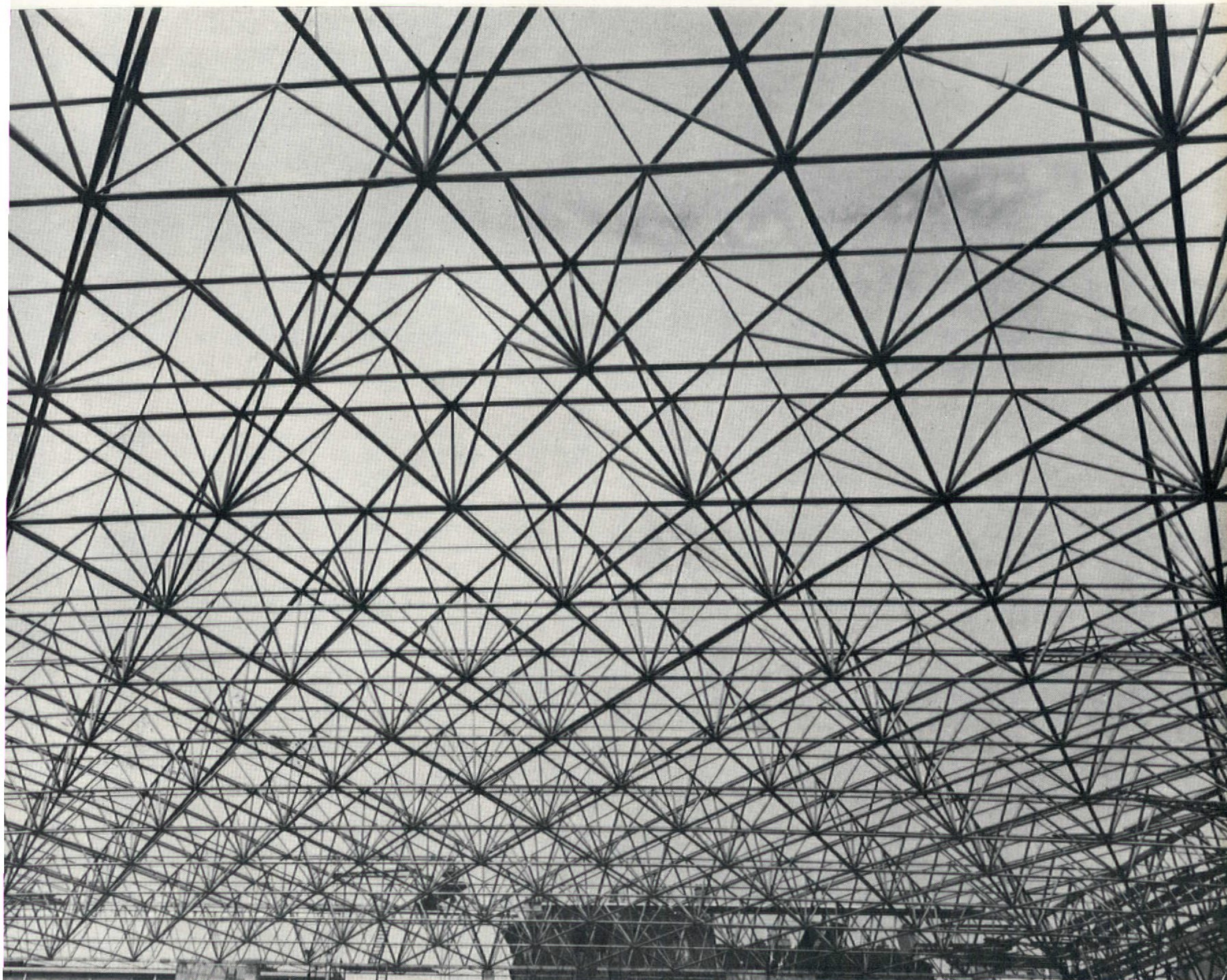
This process developed by C. E. Pearson is specially suitable for structures whose parts are identical and this applies to many types of space frames, which often consist of prefabricated identical units arranged in a regular geometrical pattern.



Above: Results obtained by the computer for the three-way double-layer grid roof structure now under construction in Madrid, Spain

A survey of recent three-dimensional structures

Professor Z. S. Makowski



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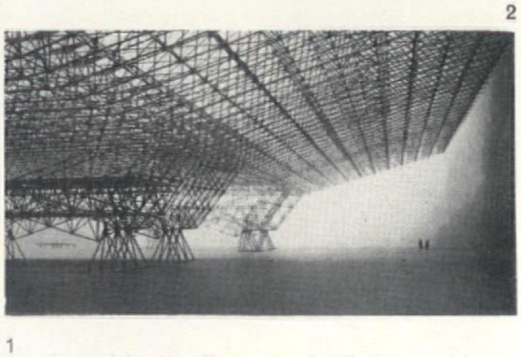


1
The largest tubular three-way double-layer grid construction in the world, 50 metres square, over a pool at Bilancourt in Paris. S. Du Château, structural analysis Professor Z. S. Makowski

2
Project for an aircraft hangar Konrad Wachsman

Many eminent architects have expressed the view that we are on the eve of a great architectural revolution, marking a change-over from the two-dimensional structures of the past to the three-dimensional space systems of the present and future.

Space frames are exerting an obvious impact upon modern architecture and there are many reasons why space structures are now gaining rapid acceptance amongst designers.

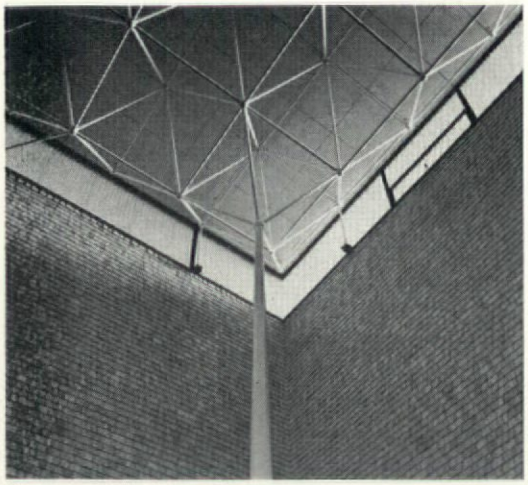
Architects claim that space structures give them greater freedom, providing them with more expressive forms.

Civil engineers appreciate the structural advantages of space frames, their inherent lightness combined with great stiffness.

The great rigidity of space frames allows greater flexibility in layout and makes possible more variation in the location of supports than in conventional systems.

Space frames have a built-in reserve of strength enabling a structure to take local overloading. It is well known that even under unsymmetrical loading, the stress distribution in space structures is remarkably even. Concentrated loads can be accommodated more easily than in conventional forms due to the omni-directional distribution of stress.

Practical experience shows, in addition, that space structures, even when badly damaged, never collapse suddenly, they start to sag; this characteristic is of great importance in case of fire.



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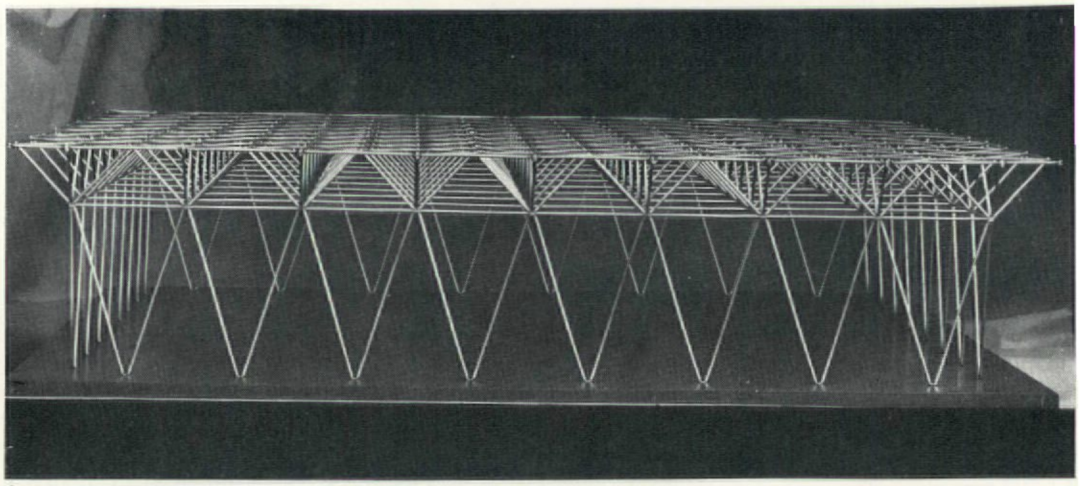

2

The emphasis put on prefabrication during recent years, has drawn the attention of designers to the fact that space frames can be built from simple prefabricated units, in most cases of standard size and shape. Such units, mass-produced in the factory, can be easily and rapidly put together on site by semi-skilled labour. At the same time the small size of the units simplifies handling and transportation problems.

The chief barriers preventing a greater use of three-dimensional structures in the past were the complexity of analysis of stress distribution and the difficulty of joining several members in space, at different angles.

These difficulties are now being overcome. Space structures as a rule are highly indeterminate, and their analysis by exact methods has led, in the past, to tedious and time-consuming calculation.

The advent of the electronic computer has changed the whole process. Now, for the first time in the history of civil engineering, it is possible to tackle very complex structural analyses with much greater accuracy than ever before and with a marked reduction in the time involved.

The use of welding has greatly influenced the present wider adoption of space structures of steel; modern techniques of prefabrication have speeded it up and standardization of component parts has led to lower costs and simplified erection.

The growing interest in skeleton space structures can, in part, be attributed to the developments and popularity of reinforced concrete shell structures. The elegance of the forms obtainable in reinforced concrete shells attracted architects greatly. For the flexibility and ease of moulding of concrete made it seem possible, to construct any desired shape. Unfortunately, they found that such systems are rather costly, due mainly to the necessity for complicated formwork.

Architects now realize that it is possible to build braced space structures more economically in steel, aluminium, timber and plastics than in concrete.

The ever-increasing number of steel and aluminium space structures built in various countries all over the world, clearly indicates that the momentum of this development is growing so that one can expect an even greater emphasis on three-dimensional structures in future.

This article is intended as a review of developments in the field of space structures during recent years. Great progress has been made in three fields, mainly in prefabrication
double-layer grids
braced barrel vaults
braced domes.

Double-layer grids

Several commercial firms specialize in double-layer grids, endeavouring to produce framing members of identical length, assembled by means of simple connectors.

The main aim is not the production of standardized buildings, but rather a standardized system of construction made of interchangeable parts of high quality, which can be erected using an entirely dry method of construction.

Double-layer grids consist of two plane networks of members (which are not necessarily of identical layout), forming the top and bottom layers, parallel to each other and interconnected by vertical and inclined 'web' members.

Basically, there are two main types of double-layer grids; lattice grids, consisting of intersecting vertical lattice girders and true space grids consisting of skeletal pyramidal units with a triangular, square or hexagonal base. In such systems, buckling of any member under a heavy concentrated load, does not lead to a collapse of the grid, because other members, even if not directly loaded and often at a considerable distance from the point of application of load, share the load, thus producing remarkably even stress distribution in the grid.

Two types of double-layer grids are particularly popular, two- and three-way grids. The first commercial two-way double-layer grid, was put on the market by Mero Ltd in 1942.

1
Steel double-layer grid, on four columns over a church in Flittard, Cologne, by J. Schürmann

2
Model of a double-layer two-way grid by Prof. Makowski, at the Building Exhibition, Olympia, 1965

3 & 4
Prefabricated two-way double-layer aluminium grid during delivery and erection, by Istvan Kadar

5
Forces in pin and rigidly connected grids

6
Design by I. Kadar for an industrial building 32 metres span, of prefabricated aluminium space trusses

7
A prototype of a three-way double-layer grid tested by Professor Makowski at Feltham

8
Prefabricated hexagonal grid in the TUC Memorial Building, London. Engineers: Ove Arup & Partners

9
A model of a three-way space grid. All the bars are of the same length, all connectors are identical. Space Structures Research Centre, Battersea College

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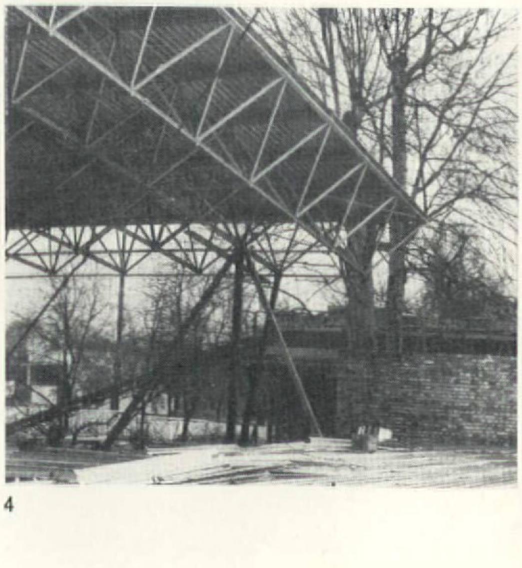

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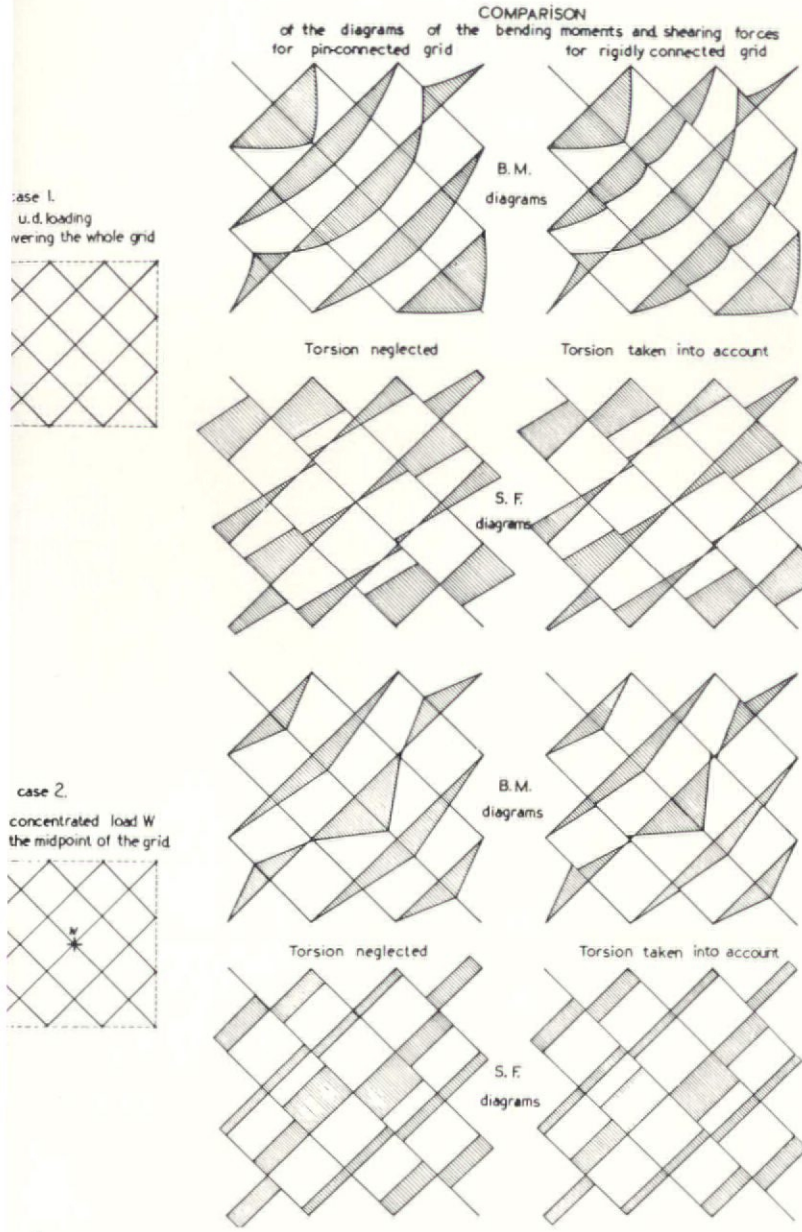
COMPARISON
of the diagrams of the bending moments and shearing forces
for pin-connected grid
for rigidly connected grid
u.d. loading
B.M. diagrams
Torsion neglected
Torsion taken into account
S.F. diagrams
case 2.
concentrated load W
the midpoint of the grid
W
B.M. diagrams
Torsion neglected
Torsion taken into account
S.F. diagrams

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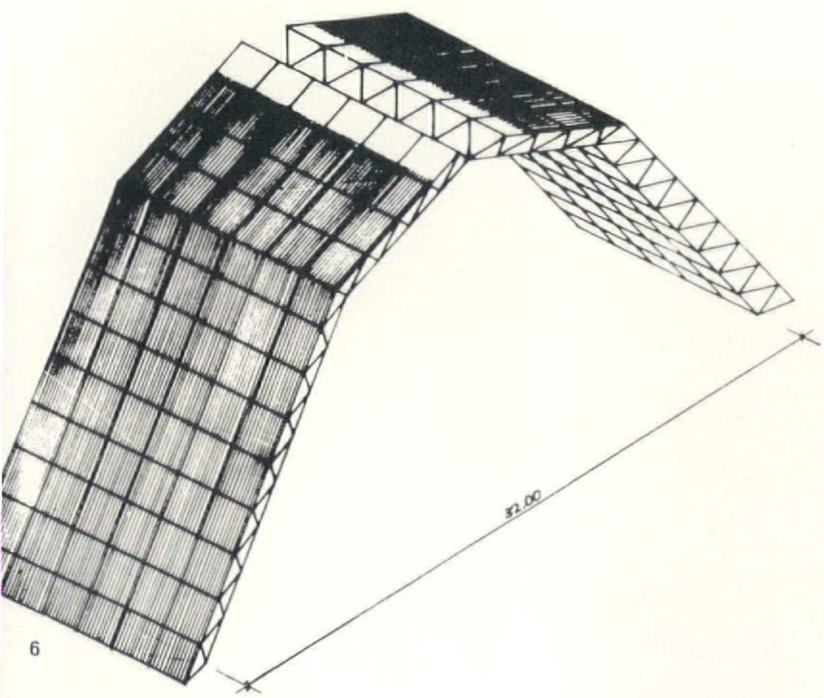
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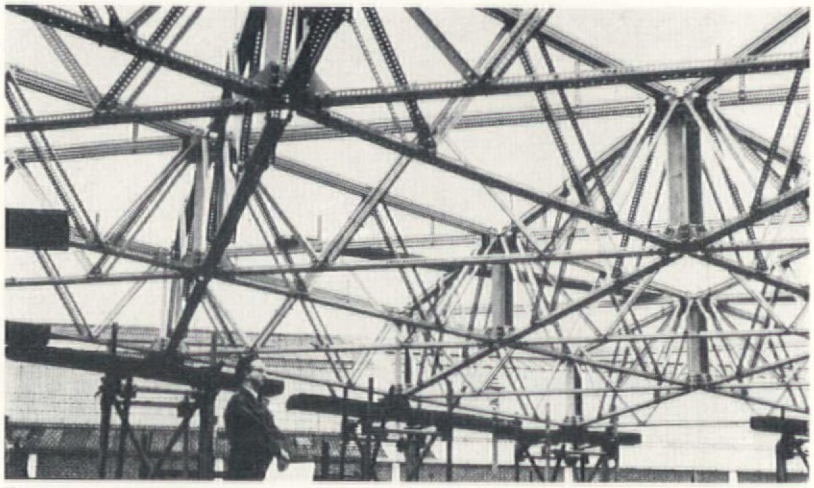

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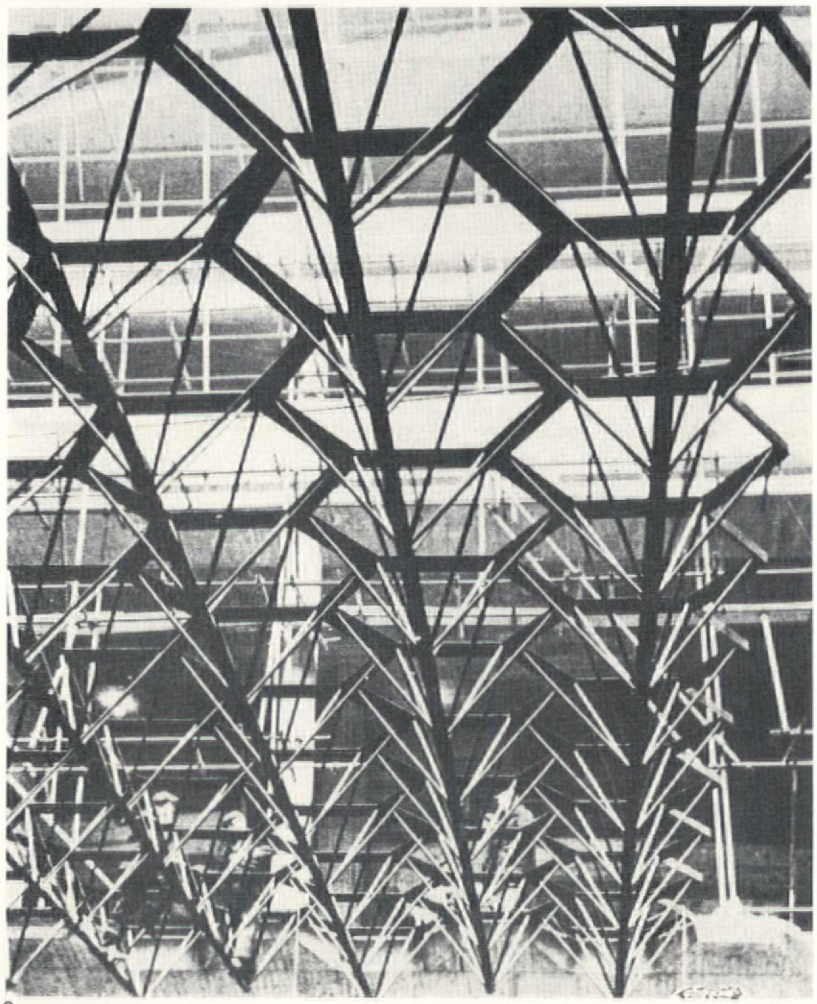

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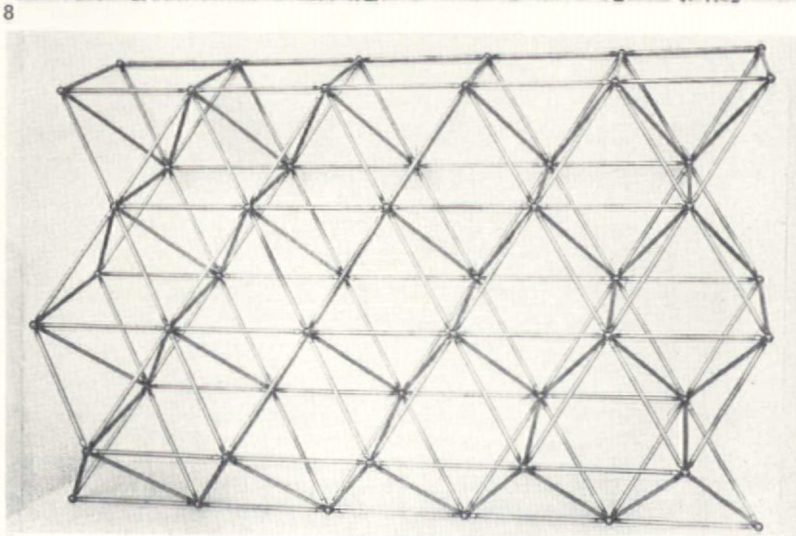

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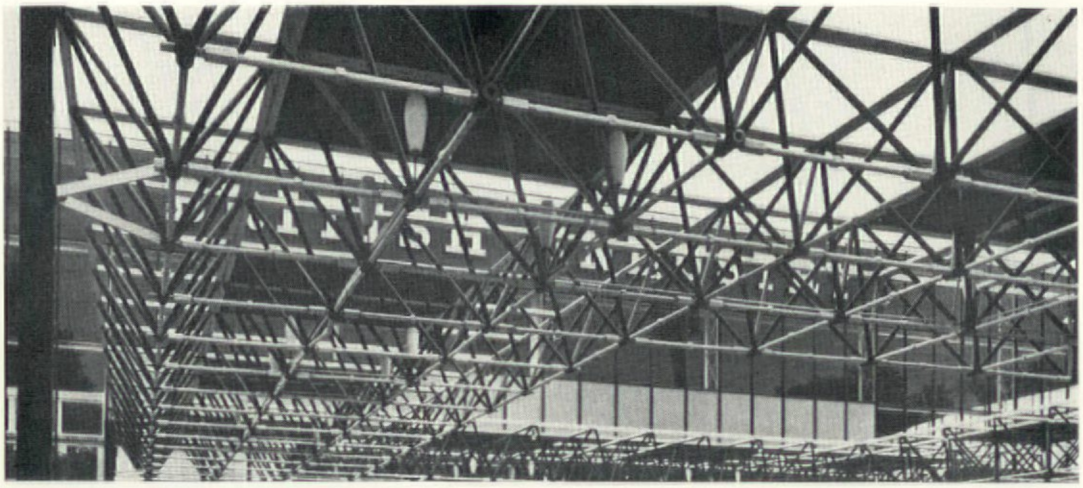

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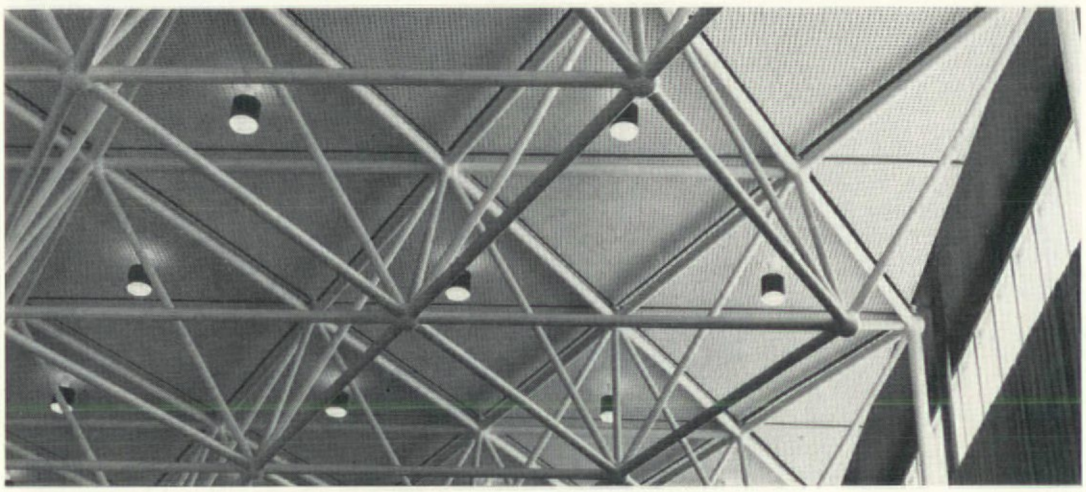

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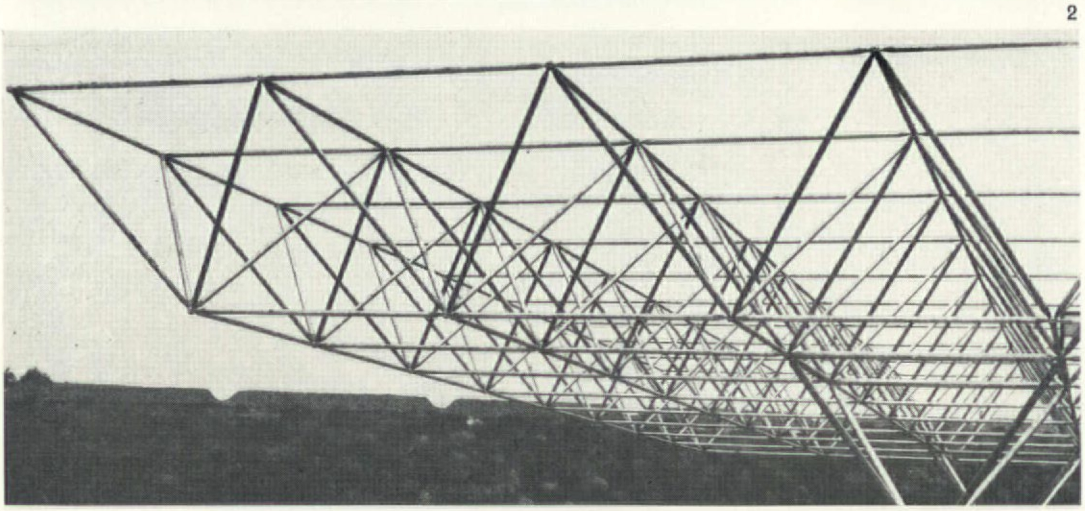

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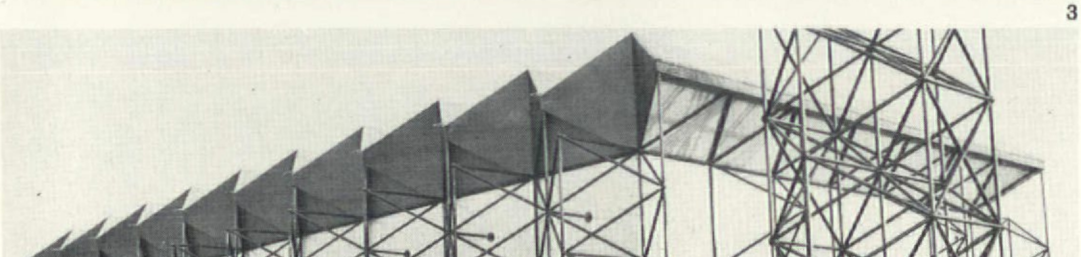

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The Mero system

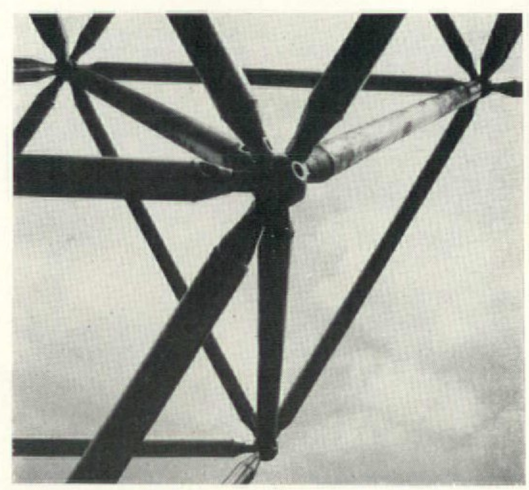
This system uses a special type of connector invented by Dr Max Mengeringhausen. Mero structures consist of tubular elements threaded into a special ball connector which enables up to 18 bars to be connected to the same node without any eccentricity. The system is extremely flexible in application and has been used in Germany and other countries for many structures widely differing in appearance and use. It has been introduced in France under the name of Tectovis. A very recent application of the Mero system is the church in Düsseldorf-Eller by Eckhard Schulze-Fielitz (*AD*, November 1964). He has produced other interesting designs, cities of the future, built from prefabricated space units, and a project for the German pavilion for Montreal exhibition—a floating pontoon of mass-produced prefabricated elements forming a three-dimensional space structure.

The Oktaplatte system

Oktaplatte is another well-known system, developed in Germany by the Mannesmann Co. after the second World War. The firm has built many steel tubular space grids for churches, exhibition halls and industrial buildings. The system involves a welded joint of two cast semi-spheres stiffened by a circular diaphragm. The tubes are directly welded to the joint. It can be used for two- and three-way double-layer grids.

Space Deck system

In England, a large number of two-way double-layer grids have been constructed by Space Deck Ltd. Their system consists of prefabricated inverted pyramids which are bolted together at



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1
Space Deck system, British Pavilion, Brussels, 1958
2
A German, *Oktaplatte* three-way grid tubular construction. The tubes are welded to a steel connector
3
A two-way double-layer grid over a factory at Dreux, France. *Mero* system known there as *Tectovis*
4
Mero-construction used for the framework of a church in Düsseldorf. Architect: E. Schulze-Fielitz
5
A *Mero connector*
6
Erection of a multi-storey building with *Nenk*
7
Unistrut construction. A school building in Michigan, USA. Architect: C. A. Attwood
8
The erection of a *Unistrut* grid over a plant at Wayne, Michigan, USA. All elements are the same length, joined together by simple connectors

the top along their common edges and have their lower apices interconnected by tie bars which are fitted with turnbuckles. Although double-layer grids have been used successfully in many countries for roof structures of large span, it has usually been assumed that such systems would not be economical for smaller spans. Recent development work, sponsored by the British Government and carried out by the Directorate General of Research and Development, Ministry of Public Building and Works, has proved convincingly that double-layer grids can compete with conventional systems even for moderate spans, and can be used both for roofs and floors in multi-storey buildings.

Nenk system

Using the basic principles of the Space Deck, Roger Walters and Ralph Iredale, both from the Directorate General of Research and Development, Ministry of Public Building and Works, have developed the Nenk method of building, which was used in 1964 for multi-storey barrack block structures built for the War Office at Maidstone, Kent. The roof and floor structures are formed by double-layer two-way grids consisting of prefabricated steel pyramids, four feet square on plan but only two feet deep. The pyramids consist of welded frames made from mild steel angles and of tube diagonals connected to steel bosses. Pyramidal units are first assembled into 'space beams' by bolting the component units together and connecting the apices with high-strength steel tie rods which have left-hand and right-hand threads at their opposite ends, so that the required camber can by provided. Several 'space beams' can be joined together into complete decks by bolting the adjacent pyramids and introducing a second system of transverse tie rods.

The pyramidal components are light enough for easy handling. They can be easily stacked together for storage or transport with little wasted space—5600ft² of floor or roof can be transported on one articulated lorry. Nenk structures are suitable for buildings up to four storeys high. Clear spans of up to 40ft, based on a super-load of 60lb/ft², are possible for floors, and up to 88ft, based on a super-load of 15lb/ft², for roofs. It is also possible, with standard units, to introduce sizable cantilevers for both floors and roofs.

American systems

Double-layer grids have been constructed by the Attwood Development Co. of Michigan. In their system, known as Unistrut, all framing members are of the same length, have identical cross-sections and can be assembled by semi-skilled labour; all connectors are identical and are so designed as to require only one bolt at each end of any member. All the units are manufactured on a special jig. This results in a very small and precise tolerance so that the individual pieces are always easy to install. The Unistrut system is thus self-aligning and self-levelling.

There are other American firms specializing in prefabricated steel grids, in particular, Up-Right Inc, who have developed a versatile system suitable for flat roofs, towers or barrel vaults. A grandstand built in California in 1961, is convincing proof of the exceptional versatility of the system, which consists of identical units joined by a universal connector.

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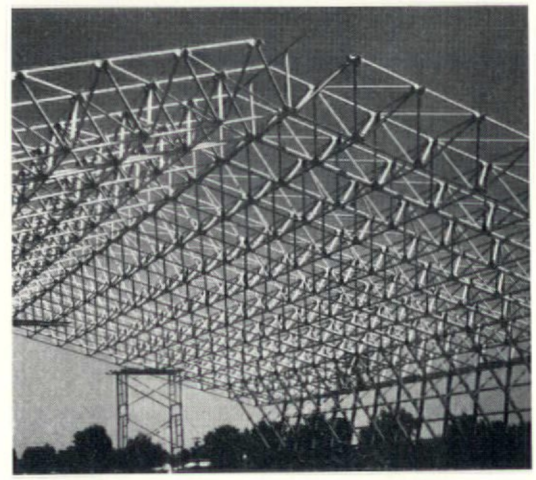

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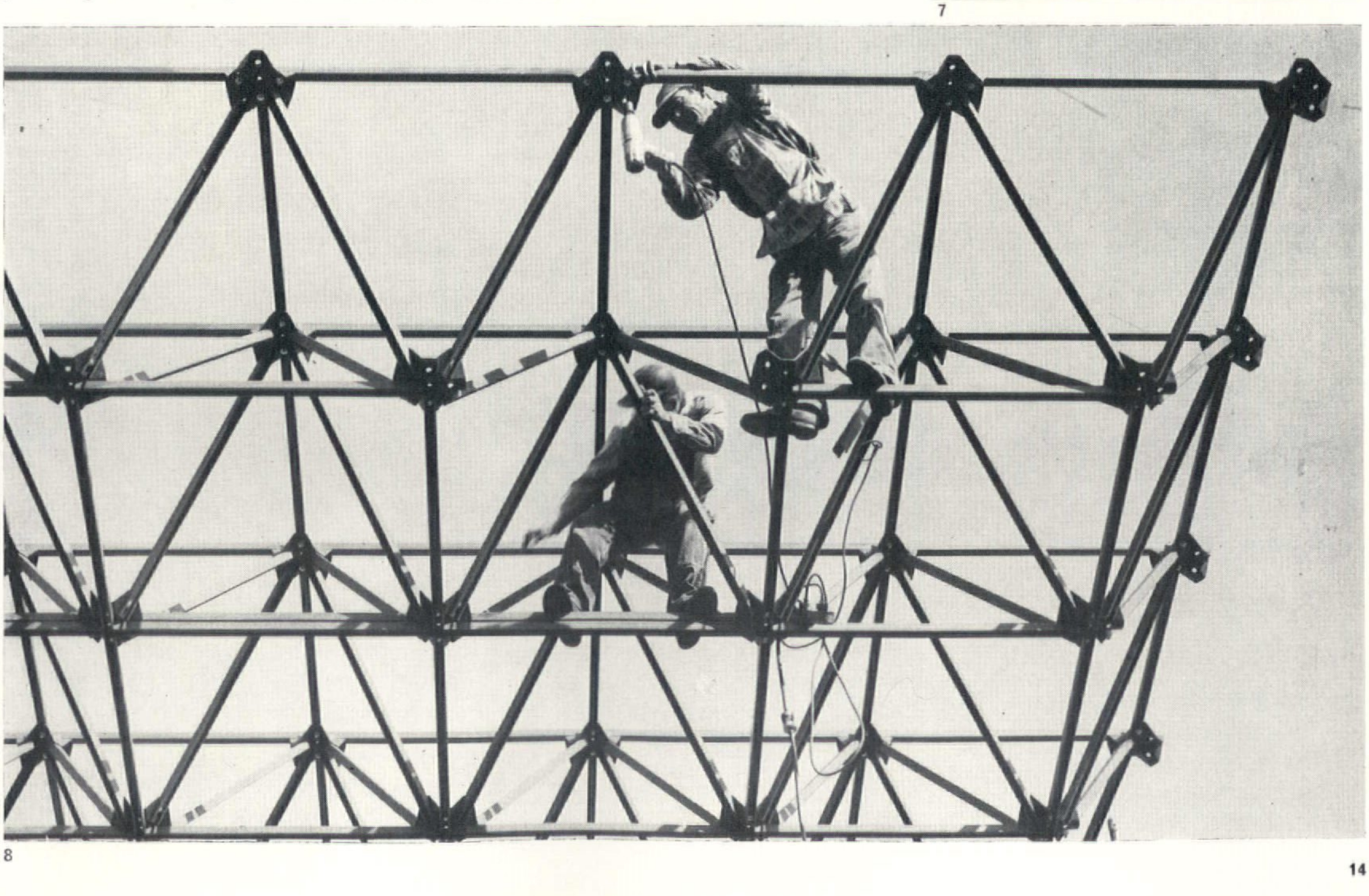

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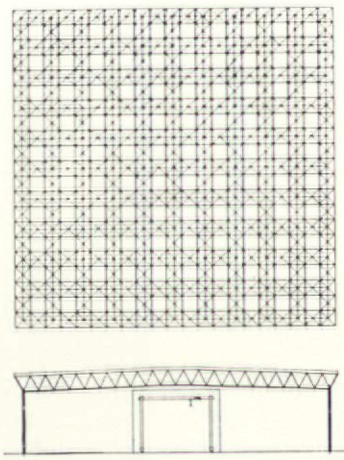

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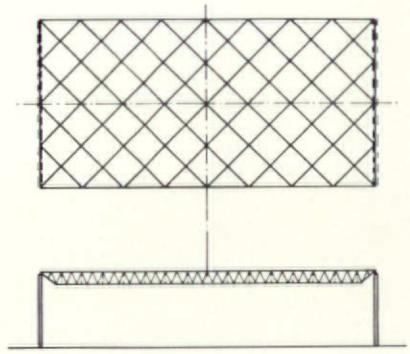

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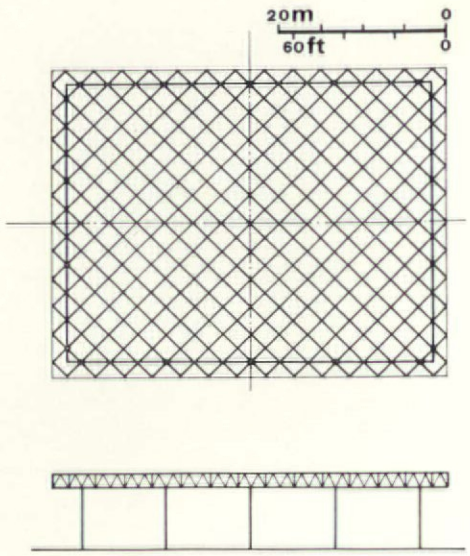

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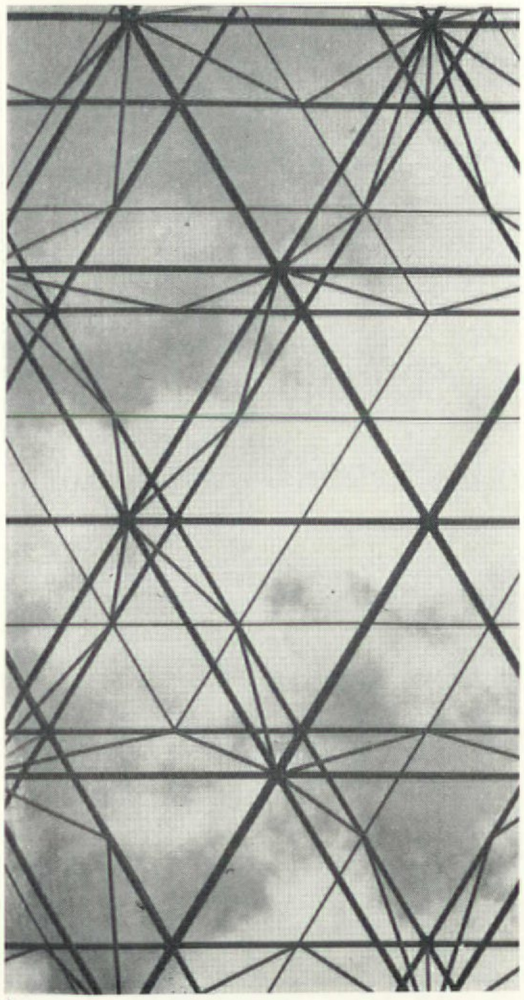

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Three-way double-layer grids

Three-way double-layer space grids appeal to architects and engineers alike, because of their attractive regular geometrical pattern and great flexural and torsional rigidity.

The structural advantages of this form of construction were realized many years ago by the French engineer, Robert Le Ricolais, now Professor of Architectural Design at the Institute for Architectural Researches, University of Pennsylvania. Le Ricolais proved that similar configurations are found in nature. The inherent economy of natural forms follows from the fact that nature builds her structures in such a way that internal forces act invariably in the direction of minimum effort. Buckminster Fuller has also turned his attention to this type of grid and has used it frequently in his structures.

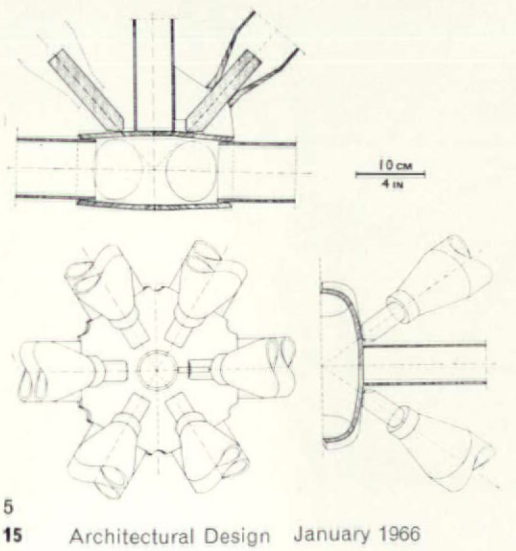
A recent example of a tubular three-way double-layer grid is the NCR Pavilion built for the 1964–65 New York City World's Fair. Deeter and Ritchey were the architects, and the engineer Eugene V. Dotter was responsible for the structural design. In order to achieve optimum strength at a minimum cost, he incorporated space frames—a three-way double-layer grid for both the roof frame and the second floor. The grid consists of tubular steel elements, all of equal length, 8ft for the roof, 4ft for the floor. The space frames, which have a very irregular layout, are supported by only three steel pylons, 62ft high, located approximately at the vertices of an equilateral triangle with sides 70ft long. The tubes, whose diameters range in size from $2\frac{1}{2}$in to 8in, have been interconnected at the joints by welding to prefabricated steel spheres. In spite of the great complexity of the layout, the space frames have been analysed by means of an electronic computer. As a result of this analysis, precise axial forces have been determined in *all* members of the grid. Even for an experienced designer of space structures, this is an achievement of great magnitude.

Steel space frames

There is little need to draw attention to the activities of the French consulting engineer, S. du Château. He is well known, not only in France, where he is the leader of steel space structures, but throughout the world.

During the last five years, he has built many frames, all of them in steel. Two years ago, he introduced into France, a system of a prefabricated double-layer grid, known as the Pyramitec. It has proved to be very economical and has been used with great success for many industrial buildings. Recent examples of such structures, covering large spans, are the roofs over the factories at Briare, La Flêche and Sorbiers. A further improvement is his prefabricated space system known as Tridimatec.

Du Château's most spectacular design is the National Exhibition at Nancy, France. This



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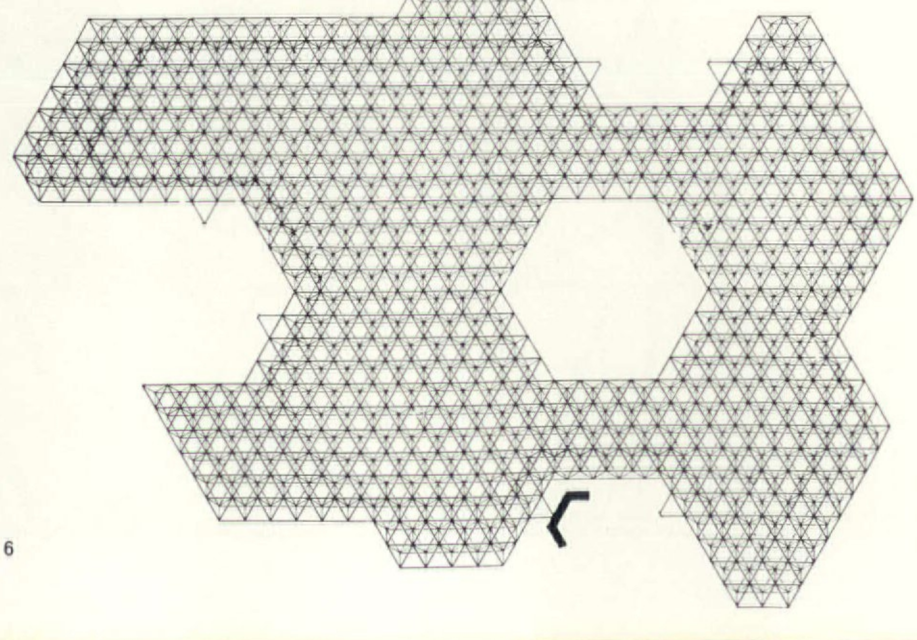

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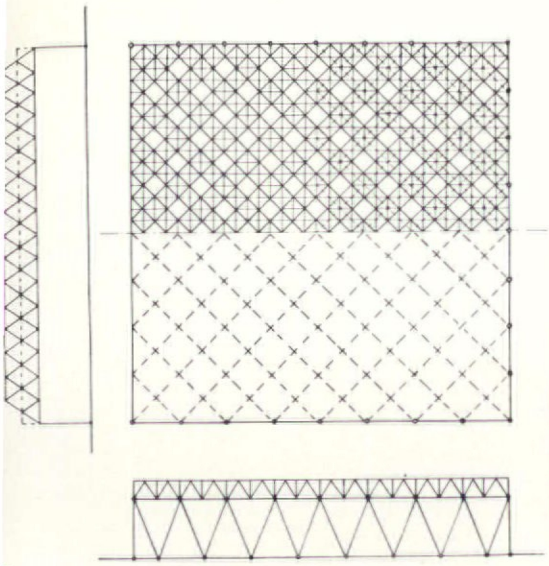

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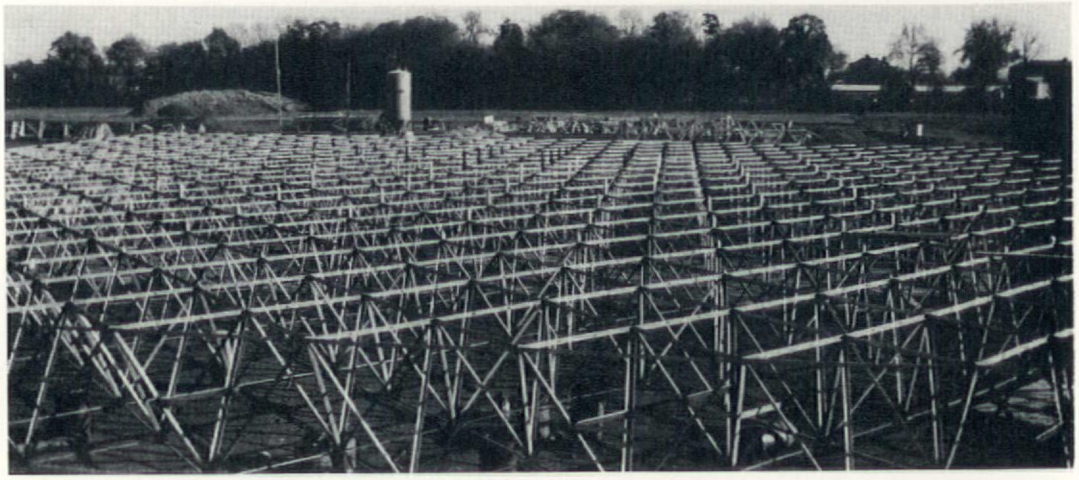

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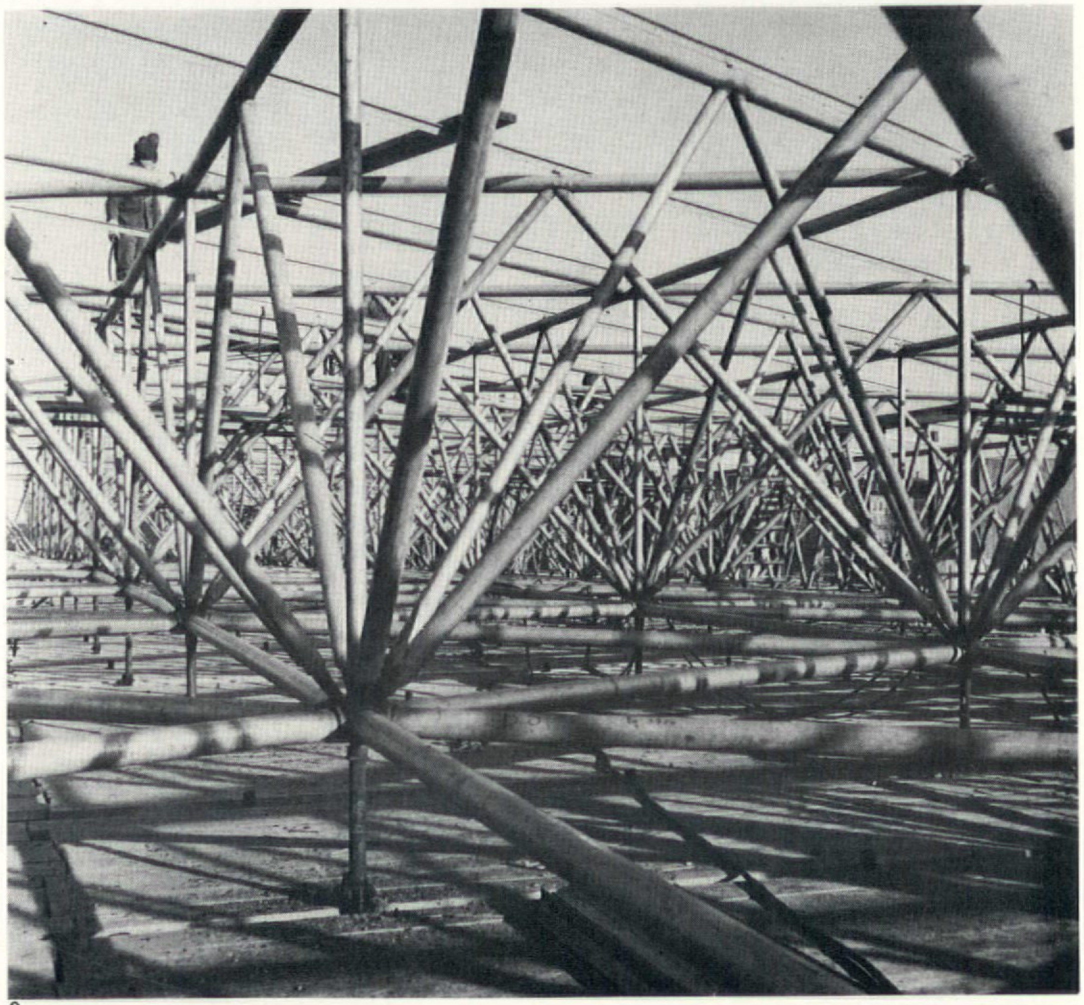
exhibition, which opened in 1964, is housed in five large span pavilions covering an area of over 183,000ft^2. Three identical halls of square layout have a clear span of 149ft, one double hall measures 149ft × 298ft, and the largest hall covers an area 149ft × 486ft, without internal supports. The pavilions are covered by double-layer grids consisting of prefabricated steel pyramidal units, all of the same dimensions. For greater rigidity, the structure is arranged as a diagonal two-way double-layer grid. The prefabricated units are made of angle sections connected by welding and are mass-produced in a jig in the factory and erected on site by bolting. Some 900 tons of galvanized steel are used in the construction. The erection was extremely simple, all the roofs being assembled at ground level and hoisted up bodily, using only four erection towers.

An analysis of these normally statically indeterminate structures, was carried out by the Space Structures Research Centre at Battersea College of Technology in London, using a specially developed programme for the electronic computer.

In recent years du Château has also built several large-span three-way latticed steel grids. An example is his 50m × 50m roof over the swimming pool in Boulogne, Paris, put up in 1962. More recently, he erected a church at Nantes, covered by a three-way prefabricated steel grid having a length of 36m. Another, Notre Dame de Lourdes at Montfermeil, Seine, is nearing completion.



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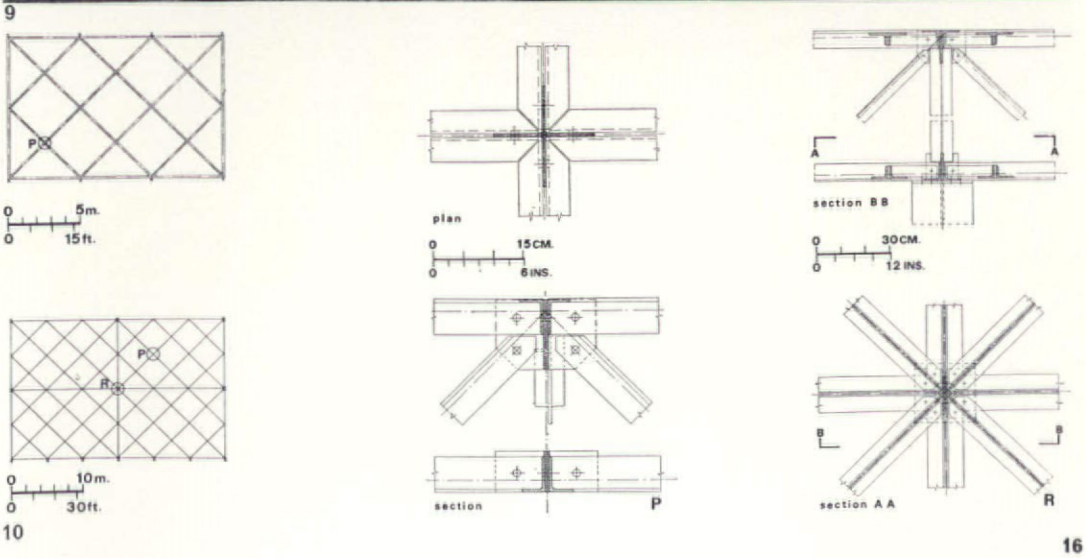

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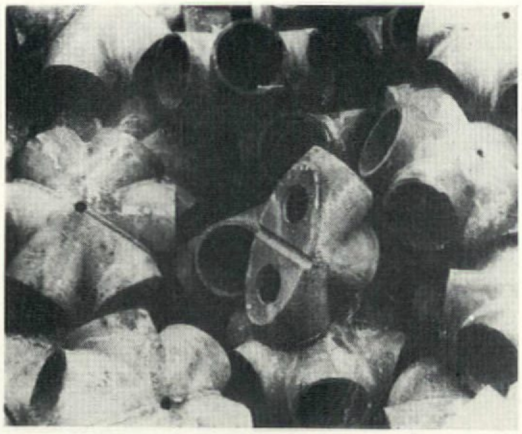
1, 2 & 3
Grid roofs over factory at La Flèche, a gymnasium in Beauvais, and another at Lagny, all by S. Du Château
4
The internal view of the three-way tubular double layer grid over a swimming pool at Bilancourt, Paris, S. Du Château. Structural analysis, Makowski
5
Details of the Tridimatec SDC connector used by S. Du Château
6
Framing plan of the three-way double-layer tubular steel grid over the NCR Pavilion at the World Exhibition, New York, 1964–65
7
Plan and elevations of the small exhibition pavilions, Nancy, 1964. S. Du Château
8
Erection of one of the Exhibition Pavilions at Nancy
9
Welded connection of three-way grid over pool at Boulogne, S. Du Château. Analysis, Makowski
10
Plans and junction details showing how prefabricated Tridimatec roof bays, 15m × 10m, are joined together and assembled. S. Du Château
1, 2, 3 and 7 are to the same scale



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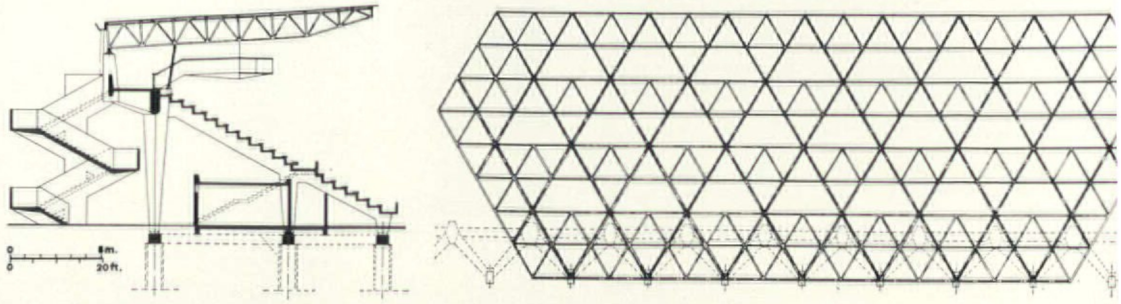

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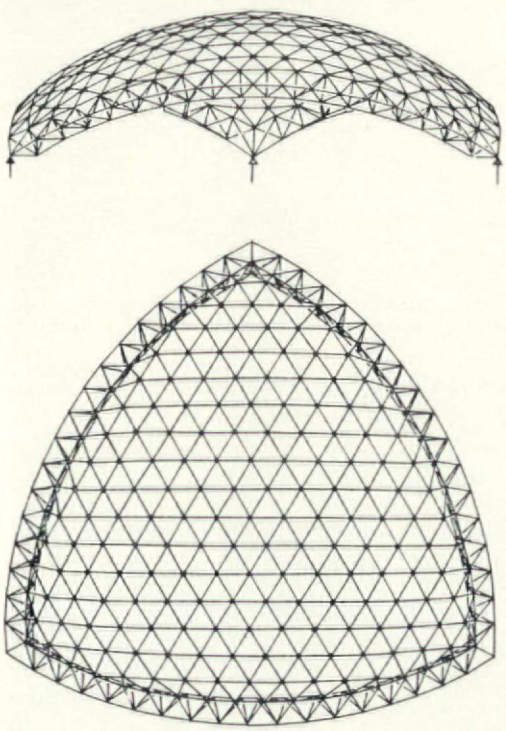

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Steel grid domes

Du Château's three-way steel grid domes are famous. The first, built in 1958, covers a power station in Grandval (Cantal) France. It has a diameter of 42m and a rise of only 6m. A more dramatic example of the three-way tubular system is his dome on a church in Chartres. For his churches he uses a special connector. The main advantage of it is that it is identical for all the nodes and allows a simple accommodation of small differences in the length of the members. For domes with small rise-to-span ratio, the tubular members are originally cut to the same length. They can both slide and rotate in the connector and it is very easy to adjust the length or the inclination of the tubes before they are welded to the connectors on site.

New connectors

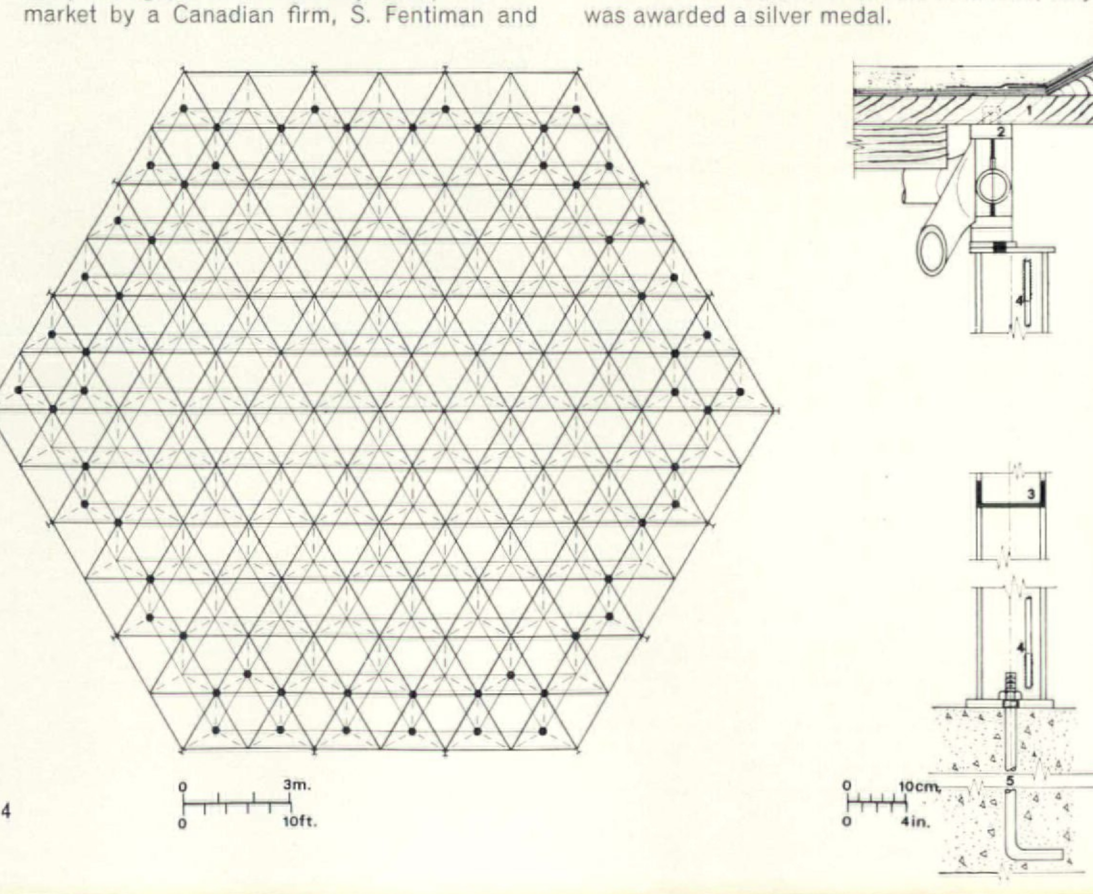
The connector is the most important part of any prefabricated system, and the final commercial success of any system relies directly on its effectiveness and simplicity. Many different types of connector for prefabricated space structures have been proposed, some have been used in practice, but only very few have survived.

The most successful connector, developed only two years ago, is the Triodetic system, put on the market by a Canadian firm, S. Fentiman and Sons Ltd of Ottawa. This connector is a breakthrough in the economic construction of space frames. It was developed originally for aluminium members, but is now being used for steel structures. It relies on a mechanical method of joining members at different angles in space without welding, riveting or bolting. An extruded hub is used, into which may be inserted members of any cross-section following the application of a deforming process to their ends, thus allowing true three-dimensional frameworks of light weight to be readily fabricated in the form of grids and shells of single or double curvature in one or two layers.

The Triodetic system will be used at the Montreal World Exhibition in 1967, to cover one of the pavilions at the Place D'Accueil. It has also been proposed for a roof grid over the halls of the University of Saskatchewan, in the form of a two-way double-layer prefabricated space frame.

A most interesting and unusual structure, known as the Sky Deck, has just been finished at Ontario, Canada. This is a tower 460ft high, in which the Triodetic system was used to form support bracing at the top.

A small boat house, built in Triodetic, as a double curved shell structure of 50ft span, erected at the recent Triennale di Milano, Italy, was awarded a silver medal.



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1
Prefabricated connector used by S. Du Château for his domes and grids

2
Section and roof plan of a grandstand at Magenta, New Caledonia, by S. Du Château

3
Steel braced dome by S. Du Château, supported at three points, over a market at Agadir, Morocco. Span 34m

4
Plan and column details of an auditorium at Smith Falls, Canada. The aluminium space grid is Triodetic, designed by S. Fentiman & Sons

1 decking
2 $2\frac{3}{4}$in × $\frac{3}{4}$in washer
3 steel channel
4 $\frac{3}{4}$in bracing rod, field welded
5 $\frac{3}{4}$in anchor bolt

5, 6 & 7
Various prefabricated Triodetic connectors developed by Fentiman & Sons

8
Three-way aluminium Triodetic grid, erected in 1963 at Camp Merrywood, Canada

9
Elevation and plan of a boathouse 50ft span, Triodetic construction, erected at the Triennale, Milan. The design received an award

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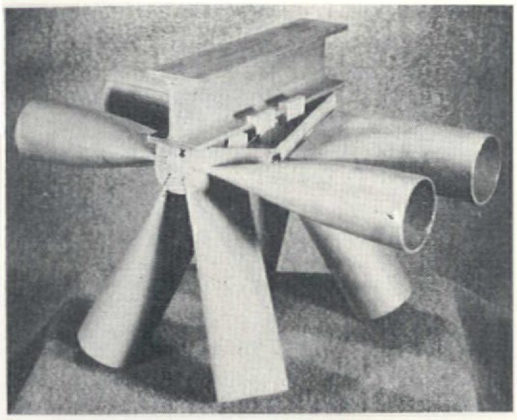
Details of the connectors used for the boathouse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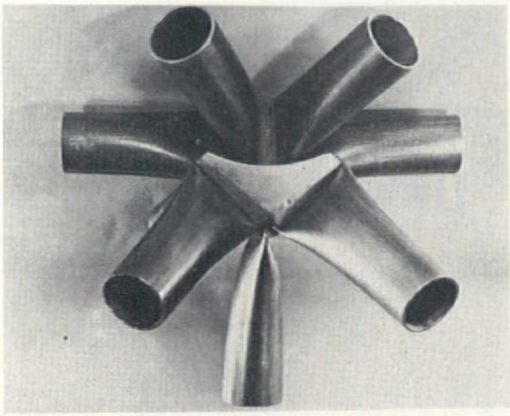
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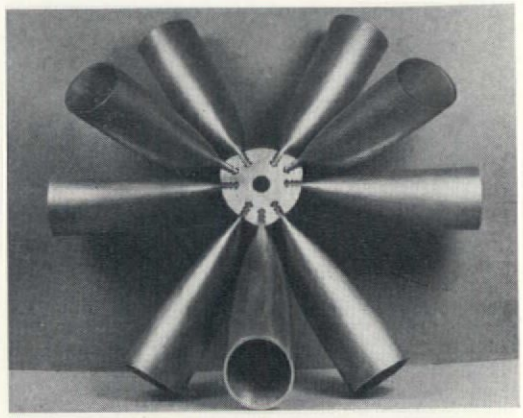
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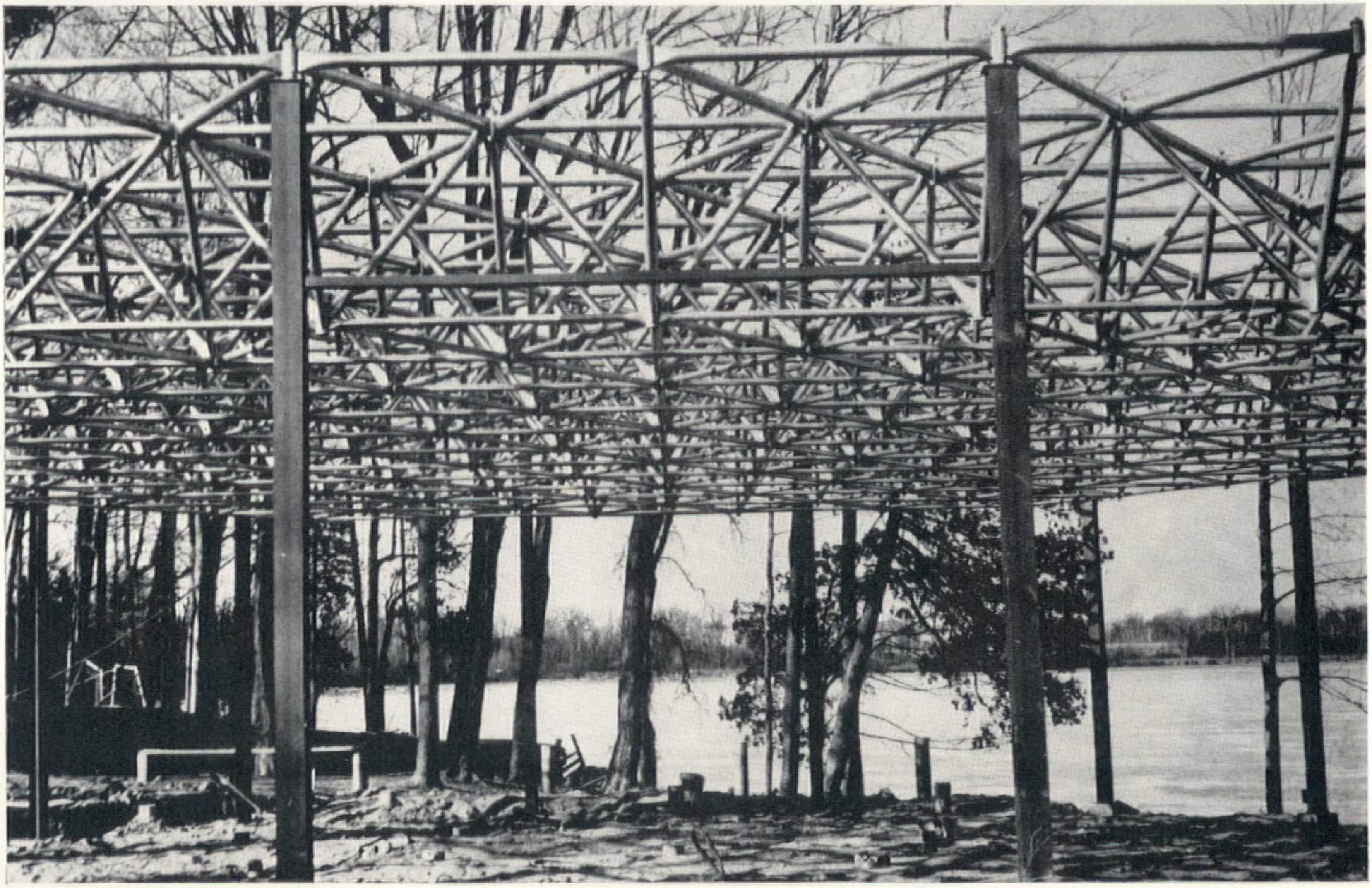
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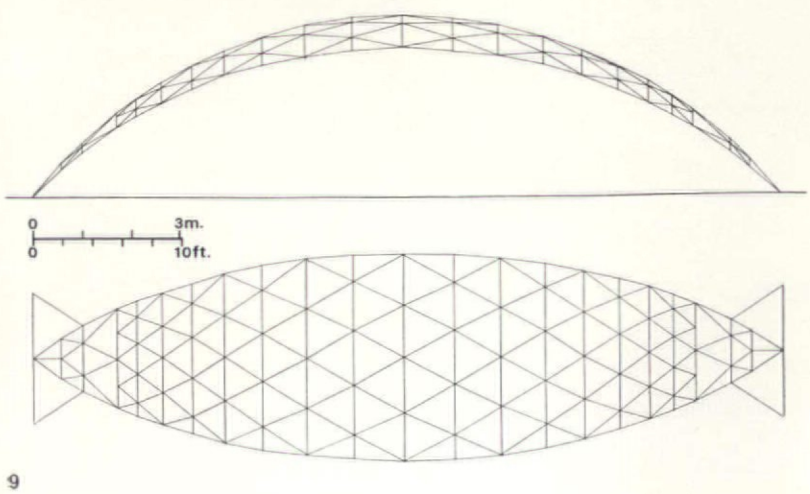

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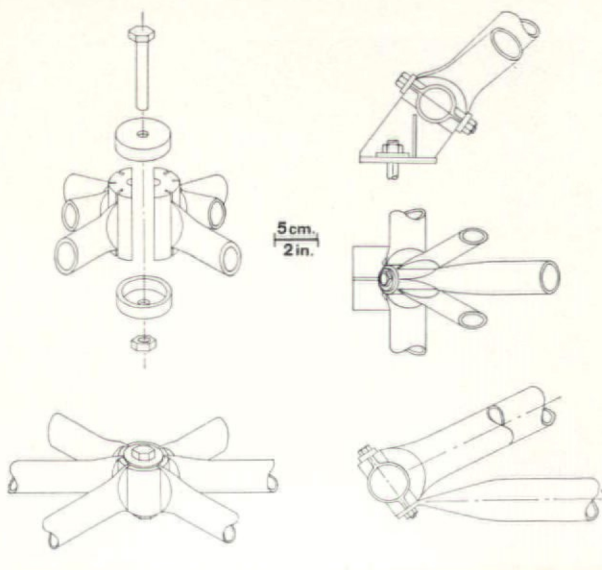

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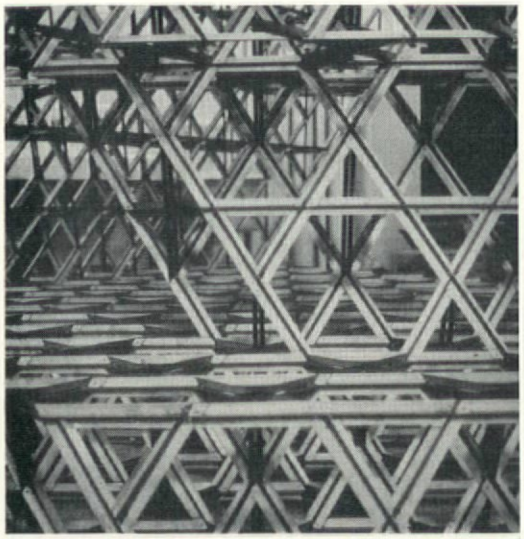

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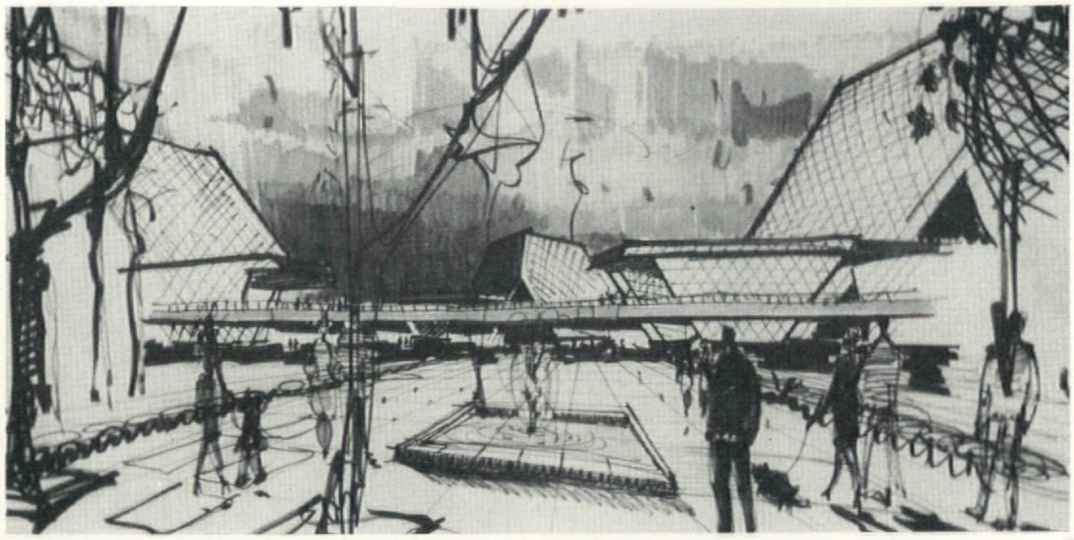

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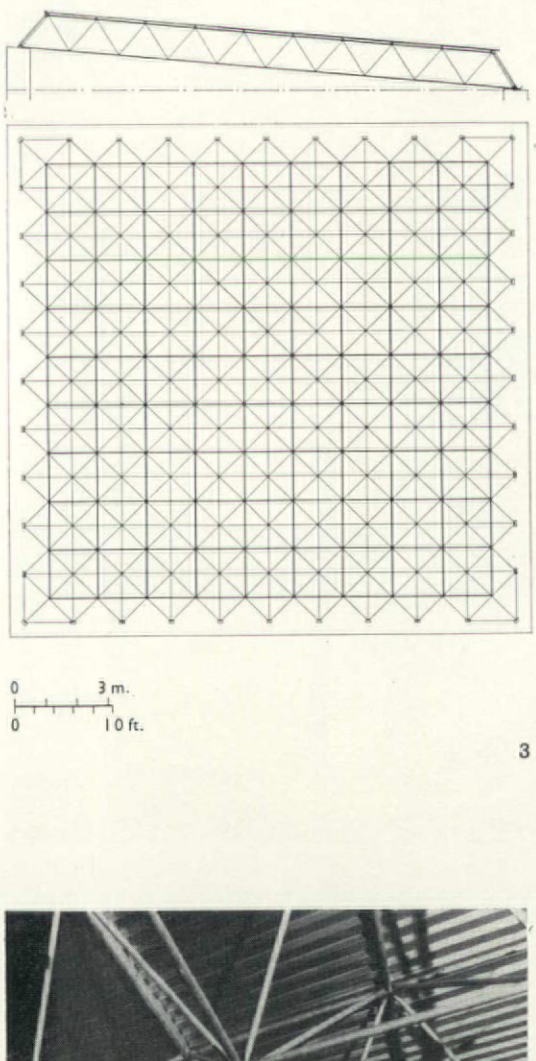

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The Triodetic system has been used in Britain. Applications include an aluminium demountable dome, erected in April 1965 in London, and a permanent structure covering a 50ft² reservoir at Tarbert, Argyllshire. This structure consists of prefabricated aluminium tubes forming a two-way double-layer grid. The whole weighs approximately one ton. Arrangements were made for an engineer of the suppliers, The British Aluminium Co. Ltd, to supervise the erection of the space frame, but on his arrival he found that the contractors, using local labour, with no experience of the system, had already finished the erection. They claimed that the erection was simpler than that of conventional roof trusses and much more rapid. In addition to being marketed initially in Canada, the Triodetic system is an entirely Canadian development.

Developments in Canada

One of the leading exponents of space frames in Canada is Jeffrey Lindsay, a former associate of Buckminster Fuller. Like the late Dr Kiewitt of Roof Structures Inc., Jeffrey Lindsay has no time for publicity; he is so absorbed in his work that it is unlikely that he notices that other people are frequently obtaining credit for developments started by him. It is probably true to say that even if he did notice it, he would not mind. Lindsay has an intuitive feeling for space structures, and although he rightly stresses the influence of prefabrication and always emphasizes the importance of industrialized systems, he rarely builds two identical space frames. He searches always for new solutions, for modifications and improvements. His structures are an excellent example of the trend towards mass-produced components of few different types with high-speed erection technique.

Mention should be made of the prefabricated aluminium domes and braced barrel vaults built by Lindsay and known as the shell truss grid. This is extremely versatile and can be applied to any shell form. The framework consists of prefabricated hexagonal space units. Six aluminium tubes form a pin-connected hexagon, stiffened by inclined flexible cables which in turn are pretensioned by a tubular vertical spreader. This forms a basic prefabricated unit, which can be used for the construction of space grids. In this type of bracing, tension and compression are completely separated and the number of compression members meeting at any joint is limited to three. Such hexagonal units can be joined together easily on site to form a three-dimensional network to make domes or barrel vaults.

A further development of this idea is made in Lindsay's work on behalf of Erickson & Massey, architects for the new Simon Fraser University in British Columbia, put up in 1965. Roof trusses are prestressed by means of horizontal spreaders. The prefabricated trusses cover the central hall of the University, which has an unobstructed area 297ft × 133ft. The top and bottom chords of the trusses (133ft long), as well as the horizontal spreaders, are of laminated pressure treated fir. The tie rods and fasteners are of high tensile stainless steel. Verticals are in galvanized steel tubes, 2½in square. Each truss is assembled in a cambered jig, hoisted up into place and bolted down to two concrete supporting rails. The spreaders are interlocked except at two expansion joints. The gutters are

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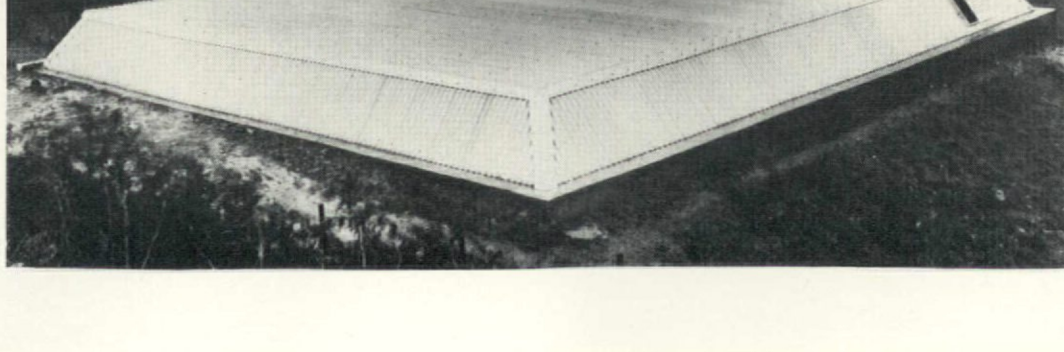

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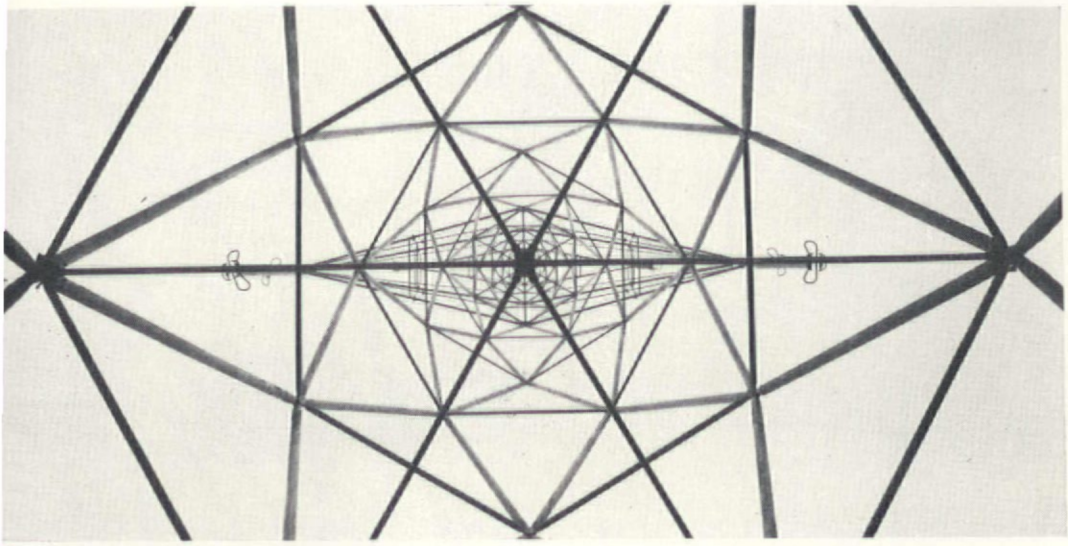
also of laminated wood, protected by an asphaltic composition and are wide enough to walk in. Jeffrey Lindsay's greatest contribution in the field of prefabricated space frames will probably be a cellular structural system for 'Expo 67'. The system, already accepted in principle by the client of two main exhibition buildings, will provide the largest space frame buildings ever erected. The architect, Jerry Miller, required a cellular prefabricated system capable of accommodating as yet undesigned exhibits, with unknown size and weights, requiring some 300,000ft² of floor area on several levels. The structure will consist of prefabricated, mass-produced steel components, making up a space-filling matrix of truncated tetrahedrons, oriented for horizontal floors and ceilings and walls with a 72° slope. According to the designers, the variations with single or multiple truss depths are unlimited.

This design emphasizes once again the necessity for close collaboration between architects, structural engineers and contractors.* The decision to use space frames confirms growing awareness of their advantages and exceptional design flexibility.

*Architects: Affleck, Desbarats, Dimakopoulous, Liebensold and Sise (Guy Desbarats with T. E. Blood). Space frame designers: Jeffrey Lindsay and Associates. Engineers: Eskenazi, Baracs and de Stein with P. Harris and Leslie Jaeger.



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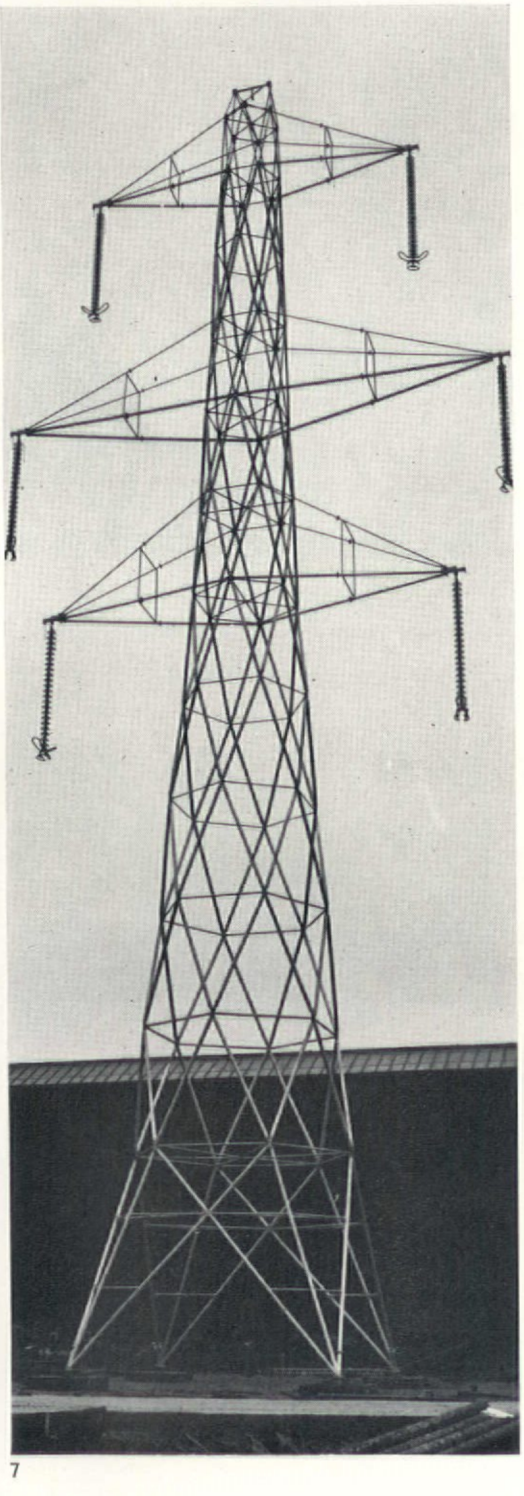

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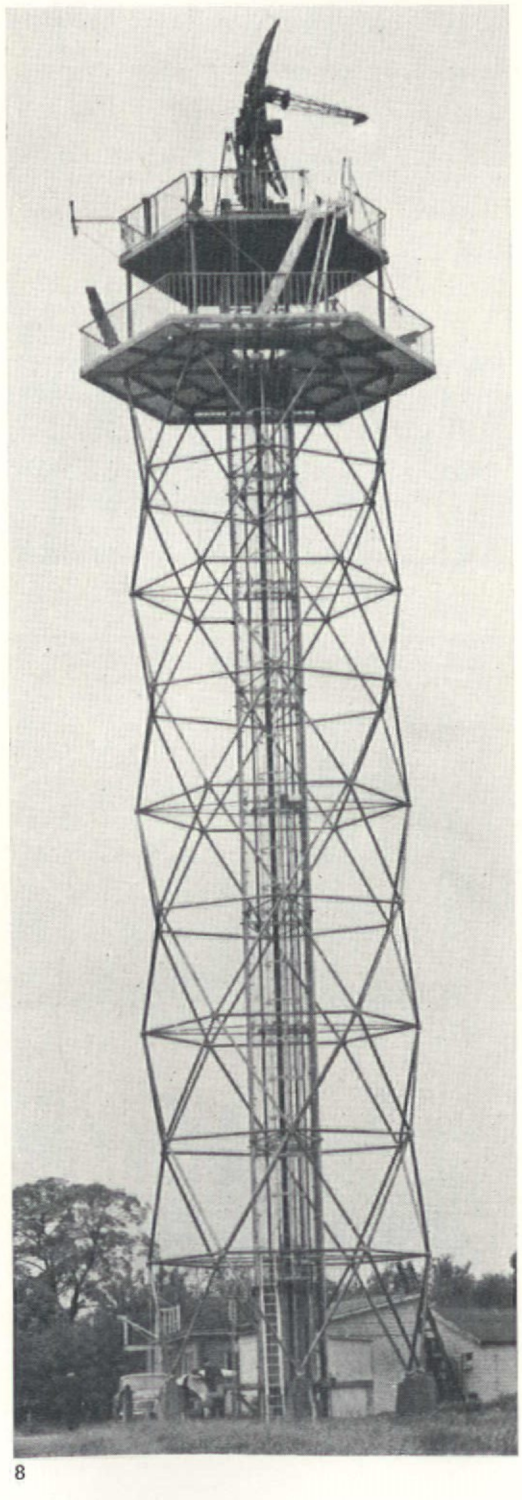

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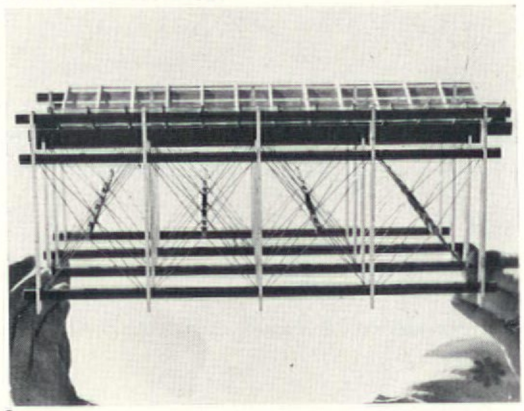

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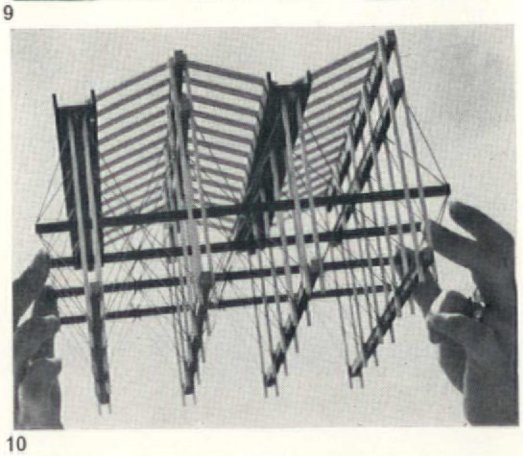

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1 & 2
Space frame for EXPO 1967, Montreal. Jeffrey Lindsay
3, 4 & 5
Cross-section, plan, and views of a reservoir at Tarbert, Argyllshire, covered by a three-way aluminium Triodetic grid
6 & 7
Transmission tower built by Tubewrights Ltd in 1965. Computer programme prepared at Battersea College
8
Radar tower built in 1965 near London. Prefabricated tubular elements joined by simple node connectors. Z. S. Makowski, D. Robak
9 & 10
Model showing the pretensioned timber trusses developed by Jeffrey Lindsay for the new Simon Fraser University in British Columbia, built in 1965

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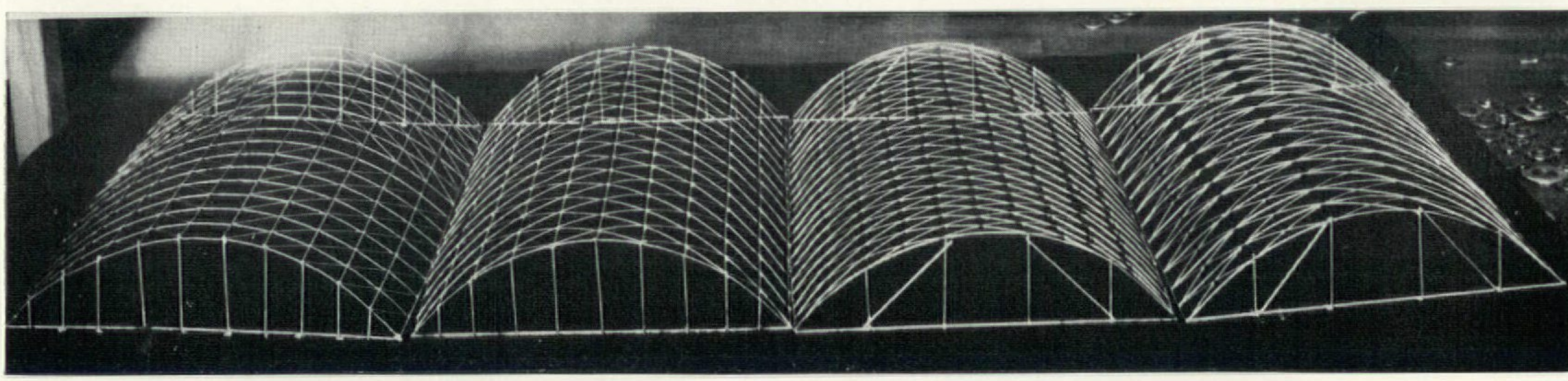

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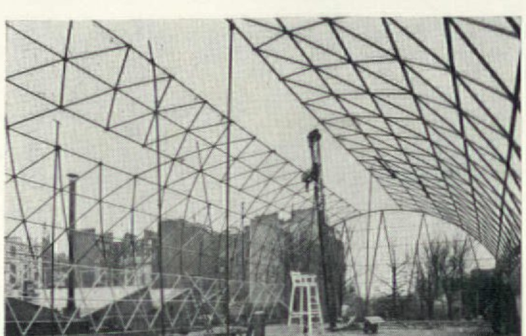

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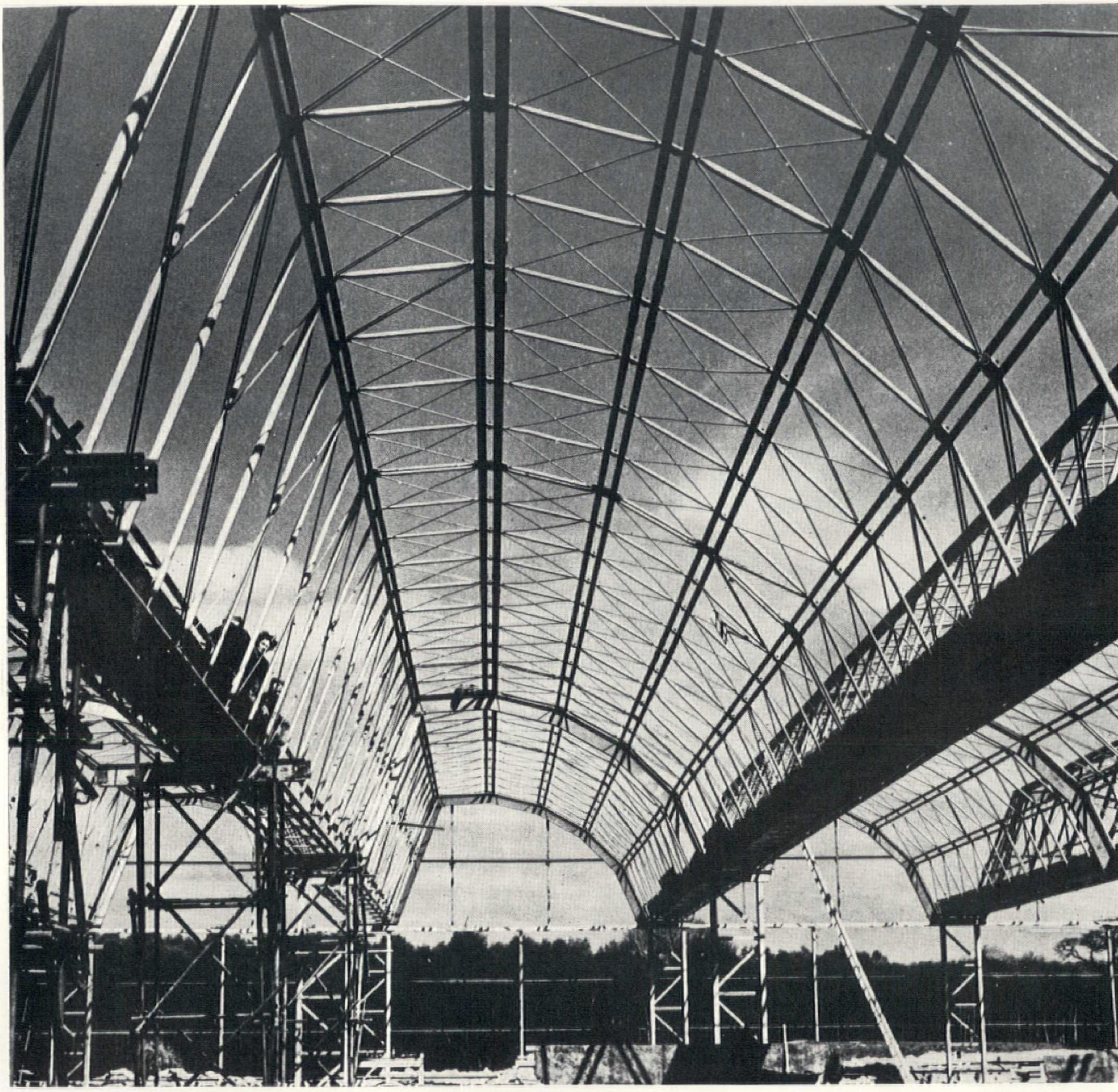

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1
A barrel vault covering a gymnasium in Carpentras, S. Du Château. Structural analysis, Z. S. Makowski

2
Models of braced barrel vaults used in the experimental investigations at Battersea College

3
Erection of a prefabricated barrel vault of the SDC type over a tennis court in Paris

4
'Lattice-shell' tubular barrel vault near London

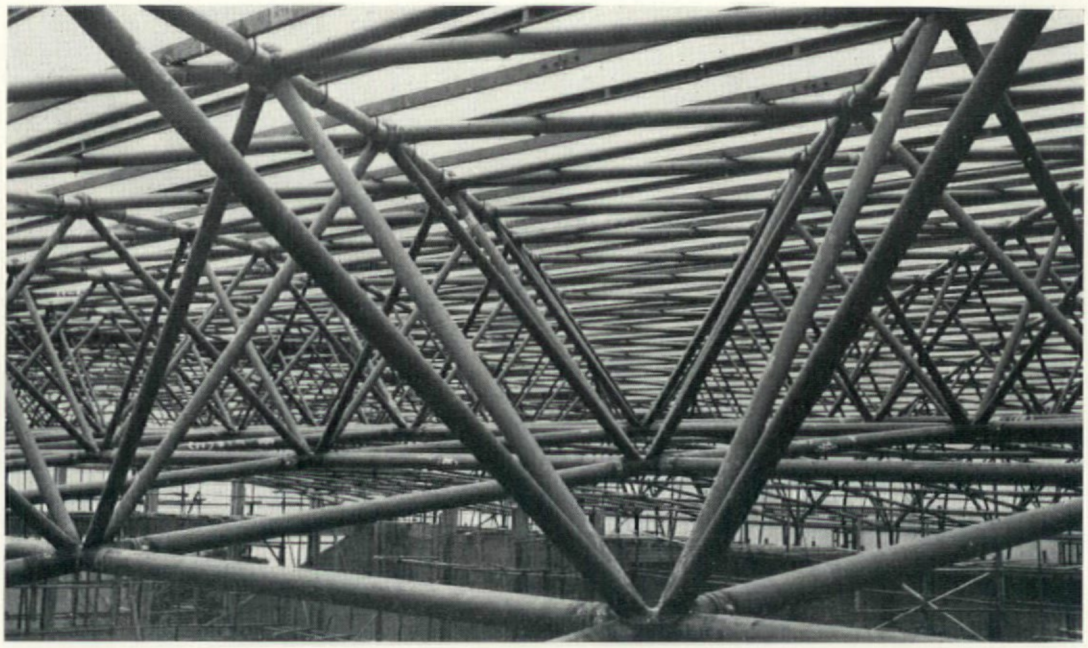
5
Erection of a Wuppermann Braced barrel vault

6
A tubular latticed stressed-skin structure covering a factory in Sussex. Engineer: F. Samuely

Braced barrel vaults

In the last few years, renewed interest has been shown in braced barrel vaults. Many industrial buildings have been covered with prefabricated systems of this type. In Great Britain the 'lightweight shell' construction developed by Mr Cyril Blumfield, has been used often as well as the 'lattice shell'. The latter system has been used to cover several churches. Du Château, in France, has designed several three-way grid braced barrel vaults. One such structure covers a tennis court at Vaugirard, Paris. The barrel vault, made from prefabricated steel tubular units, has a width of 18m and a length of 36m and is covered with translucent plastics. All the members are welded to the connectors previously mentioned, in which the tubes can both slide and rotate. The structure is remarkably light.

Timber and steel lamella barrel vaults have proved to be very popular in the USA. An association of 12 firms specializes in lamella structures.



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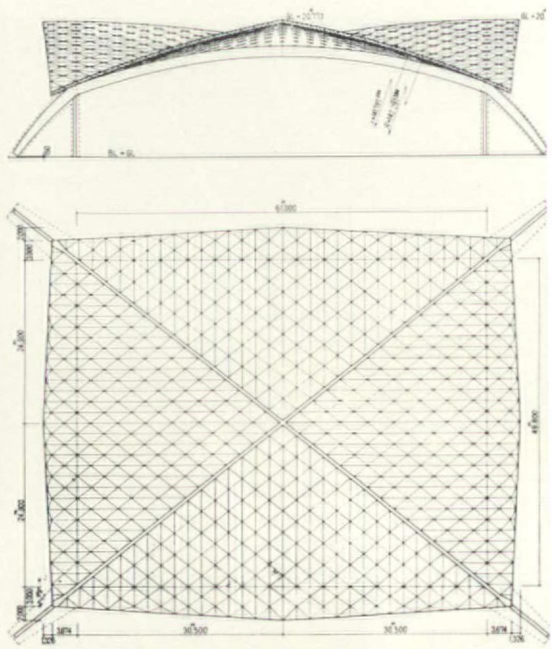

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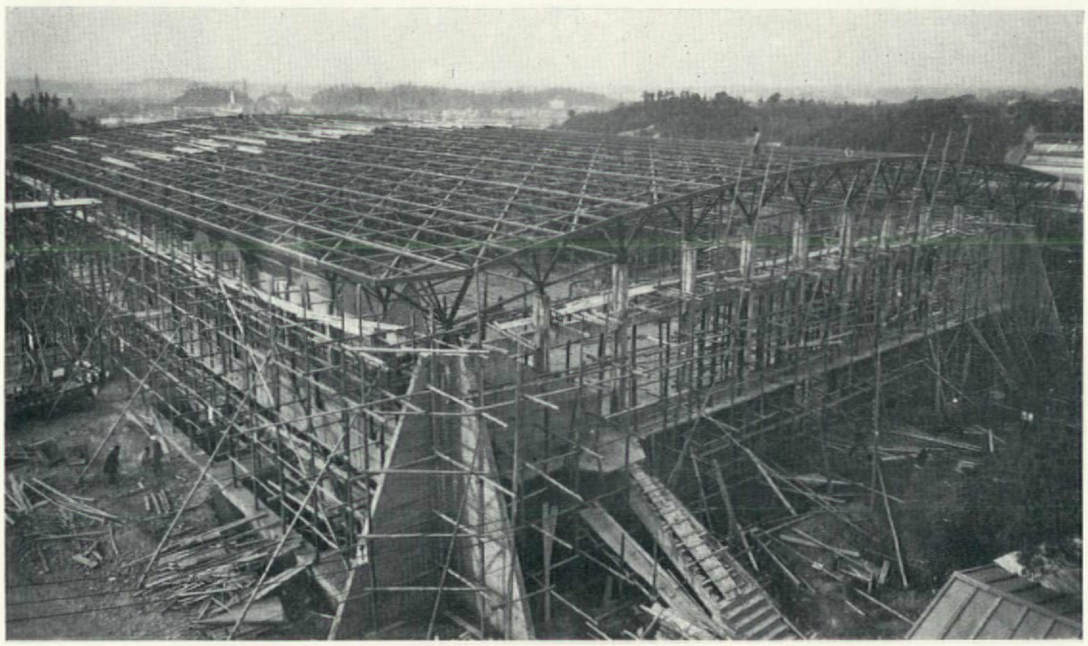

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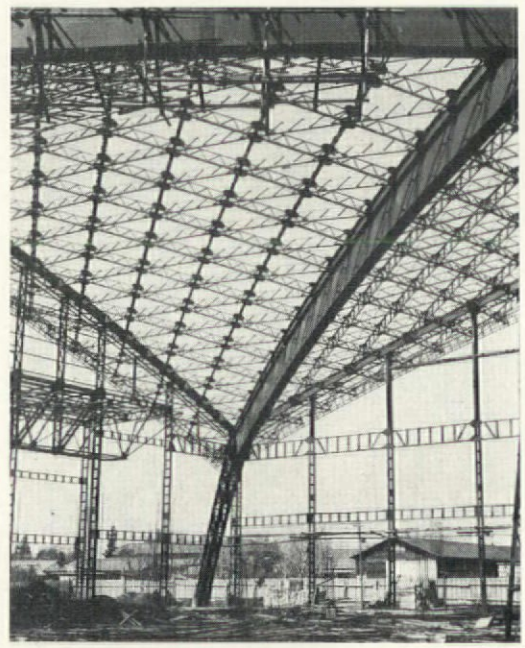

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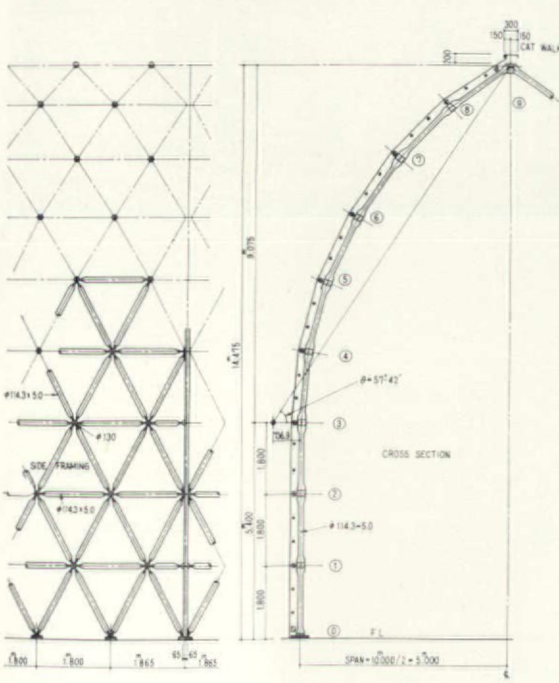
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SIDE FRAMING

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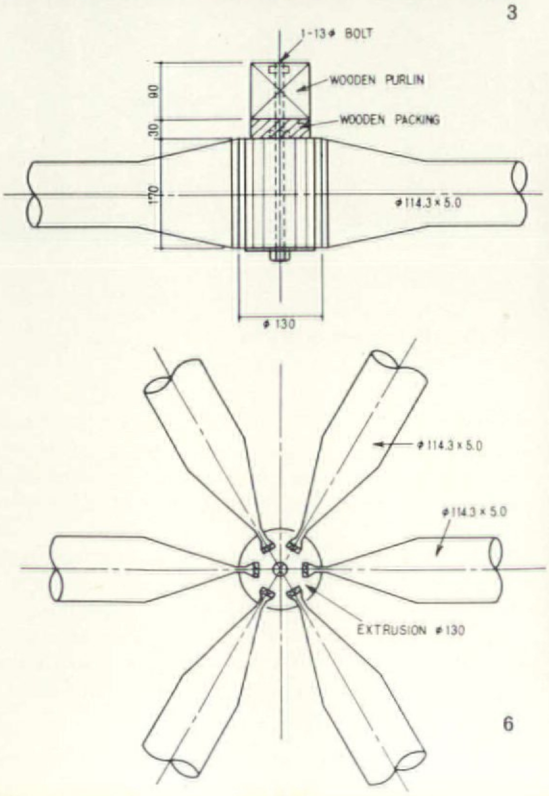
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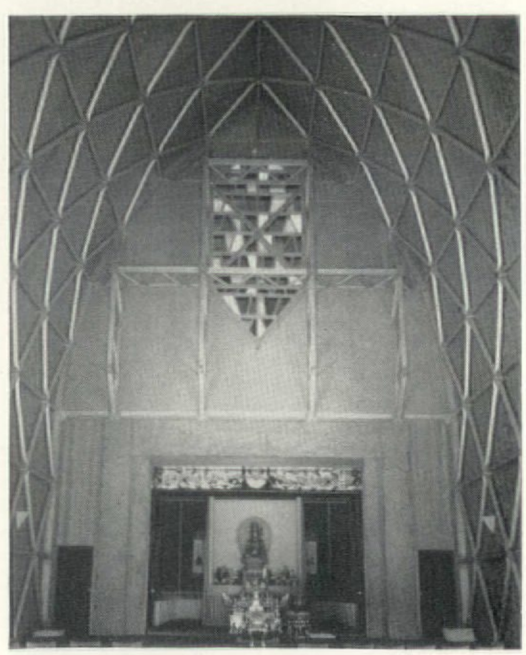

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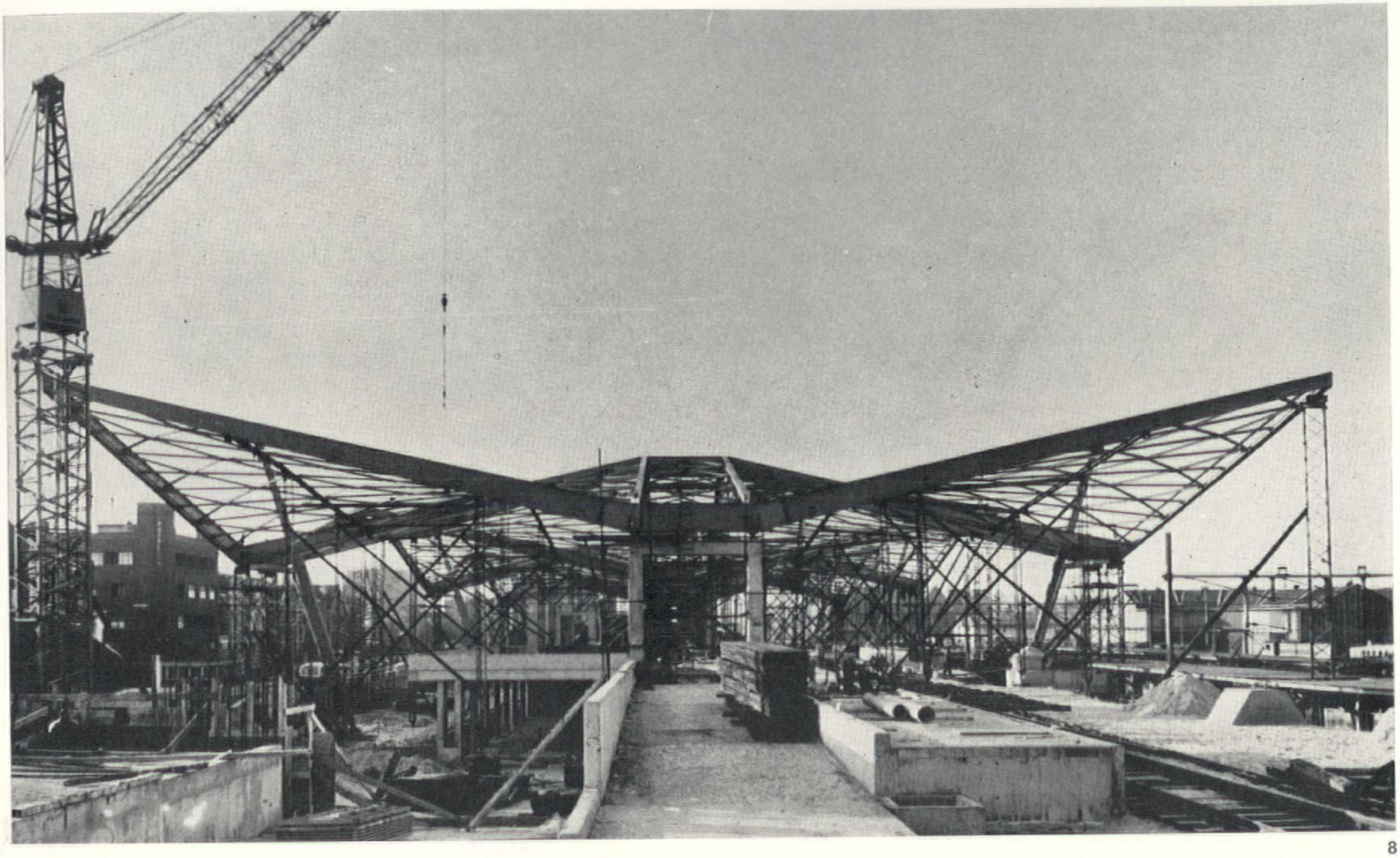

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1 & 3
Keio high school gymnasium under construction. The roof is a two-way grid of tubular steel units, site welded. Structural design: F. Matsushita, M. Sato. Construction: Tomoegumi Iron Works

2 & 4
Elevation, plan and view under construction of the Tochigi gymnasium. The roof is made up of eight curved surfaces built up with identical lattice girders. Structural design: F. Matsushita. Construction: Tomoegumi Iron Works

5, 6 & 7
Elevation, section, connector details and interior view of shrine at Daichiji. Roofed with a tubular aluminium frame. Architects: H. Kunikata, M. Tanaka. Structural design: F. Matsushita, H. Hokugo, M. Sato. Construction: Tomoegumi Iron Works

8
A braced hyperbolic paraboloid used for a railway station in Tilburg, Holland

Developments in Japan

In Japan, Tomoegumi Iron Works, has built a significant number of large-span braced barrel vaults using their 'Diamond Shell' system. The chief designer of this firm is Dr Fujio Matsushita, responsible for the design of many steel space structures. His firm specializes in the construction of prefabricated space frames. Auditoria, gymnasia, assembly halls, churches, exhibition halls and industrial buildings have been covered by their domes, barrel vaults, flat grids or braced hyperbolic paraboloids. An impressive example of a double-layer two-way grid is the huge roof over the gymnasium of the Keio High School built in 1963. The architect of this economical structure is Nissin Sekkei; the structural designer, Fujio Matsushita.

Many space structures have been erected in Japan in recent years, largely under the inspiration of Professor Yoshikatsu Tsuboi, head of the Institute of Industrial Science at the University of Tokyo. His name is specially connected with the bold design of the steel dome (span 110m) covering the International Trade Centre in Tokyo, constructed from prefabricated latticed steel units forming a three-way double-layer grid. A truly magnificent structure, satisfying from a purely aesthetic point of view and constituting a real landmark in civil engineering achievement. He was the chief structural engineer for Tange's National Indoor Stadium, Yoyogi, Tokyo (*AD*, May 1965), as well as the remarkable Municipal Gymnasium of Shimonoseki City, completed in 1963. In this case the steel space frame covers an area of 60m × 80m.

Recent developments have emphasized membranal structures in which bending is either minimized or eliminated entirely and the external loadings are transferred to the foundation by direct stresses. It is known that direct stresses are far more efficient in resisting the load than bending stresses. Hyperbolic paraboloids are examples of such structures. Architectural possibilities are almost unlimited and numerous structures of this type have been built all over the world in reinforced concrete. The beautiful hyperbolic paraboloids built by Felix Candela have attracted a great deal of attention. Many engineers now realize that it is possible to construct hyperbolic paraboloids also in timber, steel or aluminium. Some of them have proved to be very economical and a considerable number have been erected in the USA, Europe and especially in Japan. Perhaps the best example is the steel hyperbolic paraboloid covering the wrestling stadium built in 1963, in Tokyo, for the Olympic Games. It consists of latticed steel units forming a three-way bracing for the hyperbolic paraboloid, having side lengths of 70m. This huge steel space frame covers basketball courts and provides seating accommodation for 2000 spectators. The roof consists of four hyperbolic paraboloid braced shells. Normally, the foot ties of this kind of shell structure are awkward elements, which interfere with the external appearance and functional arrangements. In this structure, the architects (Yoshinobu and Ashihara) decided to locate the ties at the exterior walls of the stadium. As the four beams at the intersecting diagonals of the four shells would extend too far out if the court surface was located at ground level, the entire stadium was sunk halfway into the ground. This treatment not only made structural arrangements easier, but also brought the entrances to stands down to ground level.

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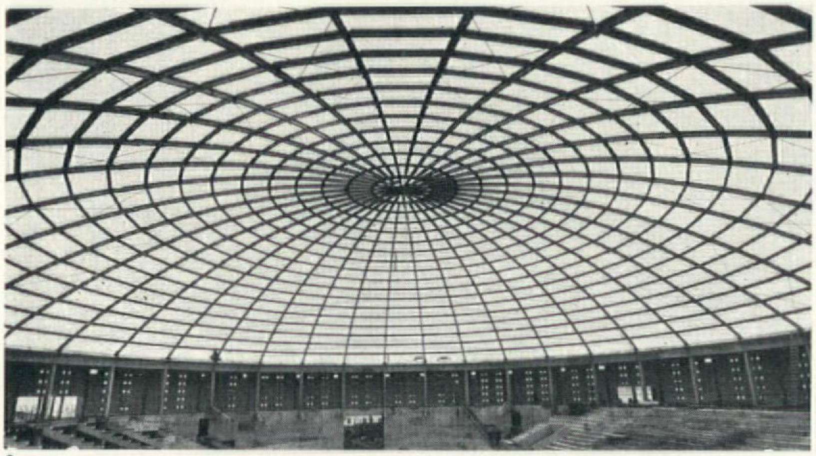

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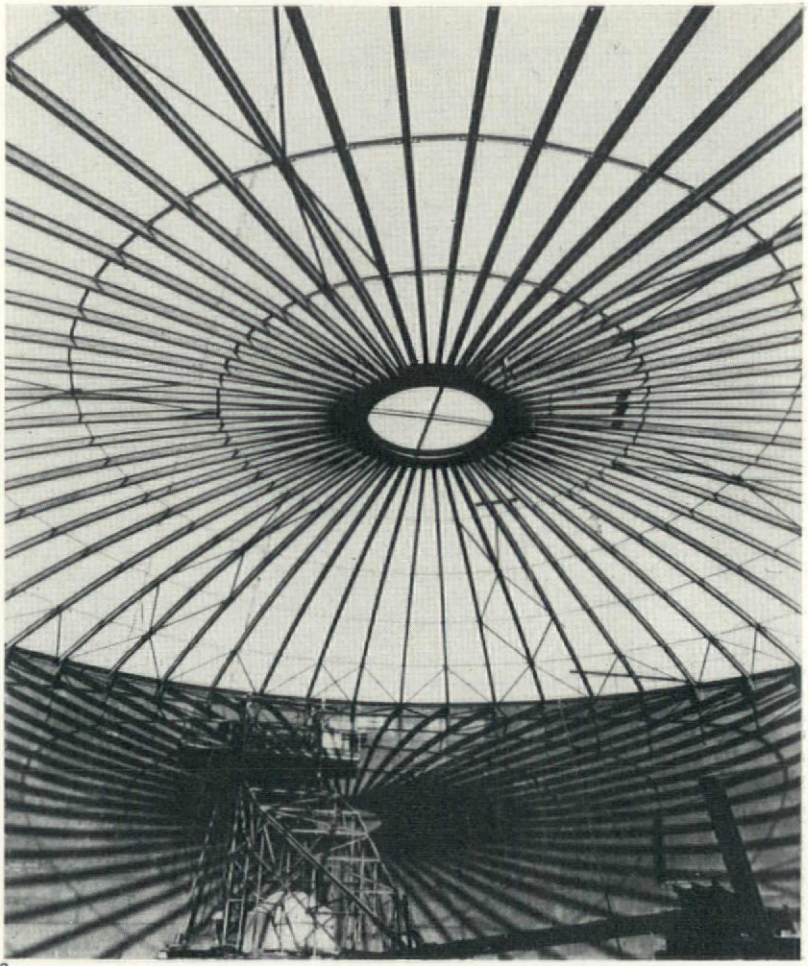


3

Braced domes

Braced domes involve an important part of engineering practice and theory. They are composed either of curved members lying on a surface of revolution, or of straight members with their connecting points lying on such a surface. Their classification is difficult, due to the great variety of possible forms. The present revival in interest is to be attributed to the great popularity of Buckminster Fuller's geodesic domes. However, many other types of bracing are possible and several of them have received special attention from architects and engineers during the past five years, because of their structural advantage over the geodesic dome.

Three-way grid domes

Because of their great strength and resistance to unsymmetrical loading, they have been used in many countries. Several extremely interesting three-way steel and aluminium domes have been built in Czechoslovakia, Rumania, Hungary, France, USA, Canada and Japan. The principle designers of these structures, are Professors Lederer, Tsuboi, Wright, Buckminster Fuller, also Dr Matsushita, du Château, Soare, Dr Kiewitt and Kadar.

Lamella domes

The steel and timber lamella domes built by Roof Structures Inc., USA, are highly economical. They consist of a large number of interconnecting units called lamellas, forming a lozenge-shaped pattern; each lamella is twice the length of the side of a diamond. At the joint one lamella unit runs continuously through with the adjacent intersecting members connecting to it at its midpoint. Roof Structures Inc., is leading in the field of lamella structures. Their recent development is the 'parallel lamella' system in which the dome is divided into a number of cyclically symmetrical sectors braced by two sets of lamella members, each parallel to one of the main radial ribs.

Several big domes have been built in the USA using this system. Good examples are the 81m diameter steel dome built in 1959 by Roof Structures Inc., over the Brown County Veterans Memorial Arena, or the 78m diameter dome covering the City Coliseum in San Angelo, Texas. The biggest parallel lamella steel dome has just been finished in the USA. It covers the Harris County Sports Stadium in Houston, Texas. The dome has a clear span of 642ft and is thus the biggest dome in the world. Built by Roof Structures Inc. and designed by Dr G. R. Kiewitt and L. O. Bass assisted by a team of experts, its surface is divided into 12 sectors each sector being divided again into six peripheral joints along the tension ring and six joints along meridian ribs. The steel lamellas are up to 120ft long; they were prefabricated in the factory and arrived at the stadium on special trailers. There is seating for 46,000 for baseball, 66,000 for conventions and boxing matches. The net weight, including not only the steel lamella units, but also the tension ring, is only 16·6lb/ft^2, a remarkably low figure for such a span.

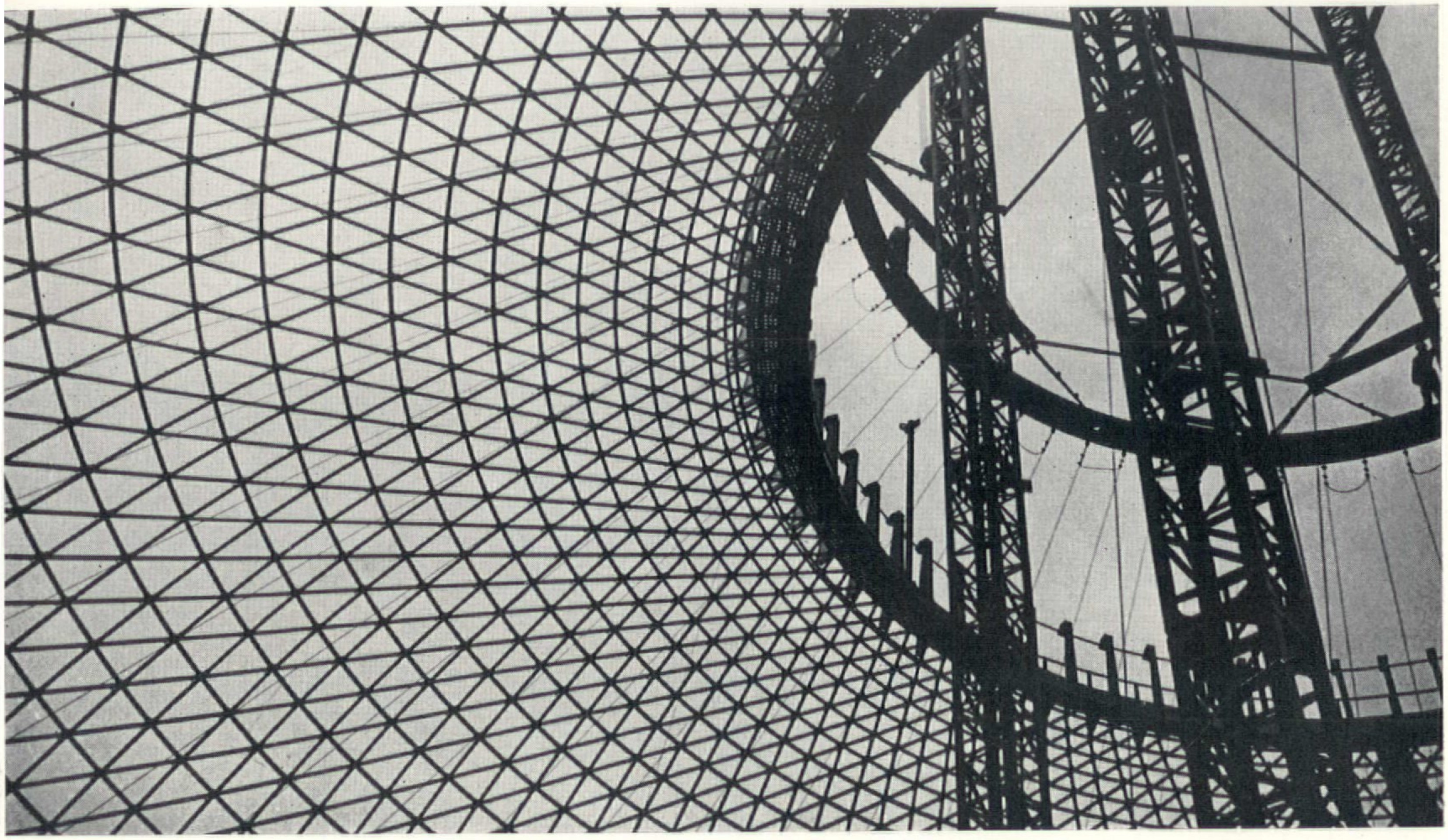
Movable domes

Another spectacular structure is the retractable domed roof in nickel stainless steel covering a public auditorium in Pittsburgh, USA. It has a diameter of 417ft and a rise of 109ft. The dome is divided radially into eight leaves, slightly differing in size so that they can be nested. Six of the leaves are movable and two stationary. At a touch of a button, the six movable leaves, each weighing some 300 tons, roll round into the nested position above the two stationary leaves.

Light designs

The honour of one of the lightest dome structures in the world for its size and applied load should go to the steel ribbed dome built in 1963 for the Pacific National Exhibition Agrodome Building, Vancouver, Canada. It is a spherical steel grid system, having a clear span of 225ft and consisting of 36 meridian rafters and 17 rows of concentric ring purlins. Every second row of panels has been stiffened by diagonal cross-bracing consisting of tension rods installed to resist panel shear. The dome is light and economical because of the prefabrication of the ribs and the great simplicity of erection. Covering 40,000ft^2 of uninterrupted floor area, the steel framework weighs only 7·3lb/ft^2 of floor. The cost of the erected roof was only $2.30 per ft^2 of floor. This price included also field painting and the timber roof deck. The structure was designed by Mr Heino Loo, Senior Design Engineer of Western Bridge Division of Canada Iron Foundries.

1
Braced dome of the Kiewitt type over the Armory Building, Little Rock, Arkansas
2
Steel dome, Vancouver. Engineer: Heino Loo
3
Ribbed steel dome over an oil tank at Brunsbüttelkoog
4
Erection of a tubular dome, span 310ft, at Brno, Czechoslovakia. Professor Lederer
5
Model of a double-layer dome. Professor Makowski
6
Auditorium with a retractable dome, maximum diameter of 417ft, at Pittsburgh, Pa, USA
7
The largest-span steel dome in the world, Houston, Texas. Roof Structures Inc. Consultant: Professor Makowski
8
Timber lamella dome built by the Roof Structures nc.



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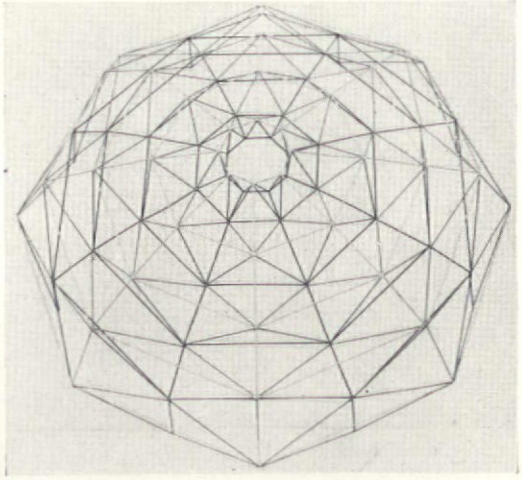

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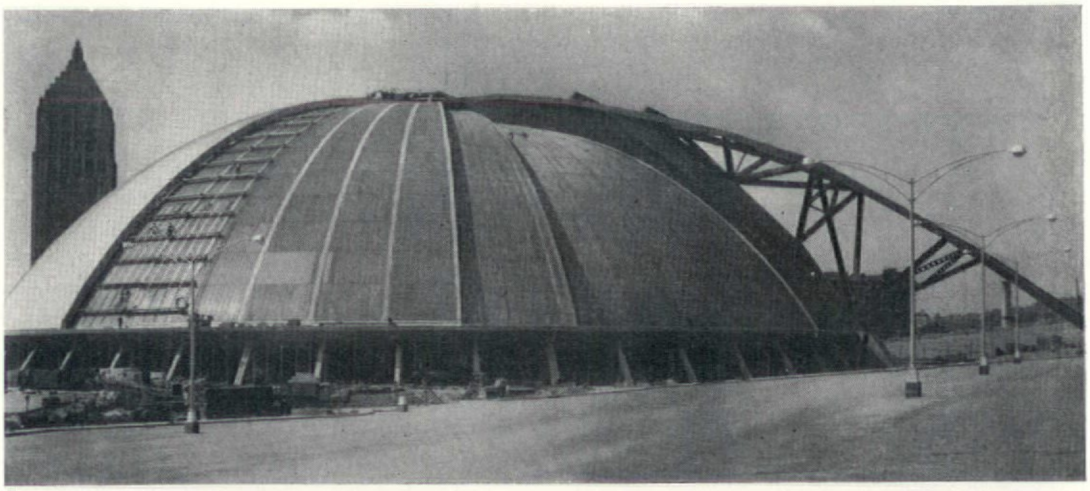

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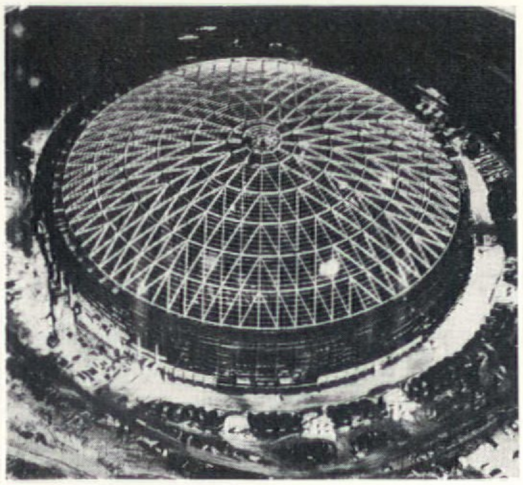

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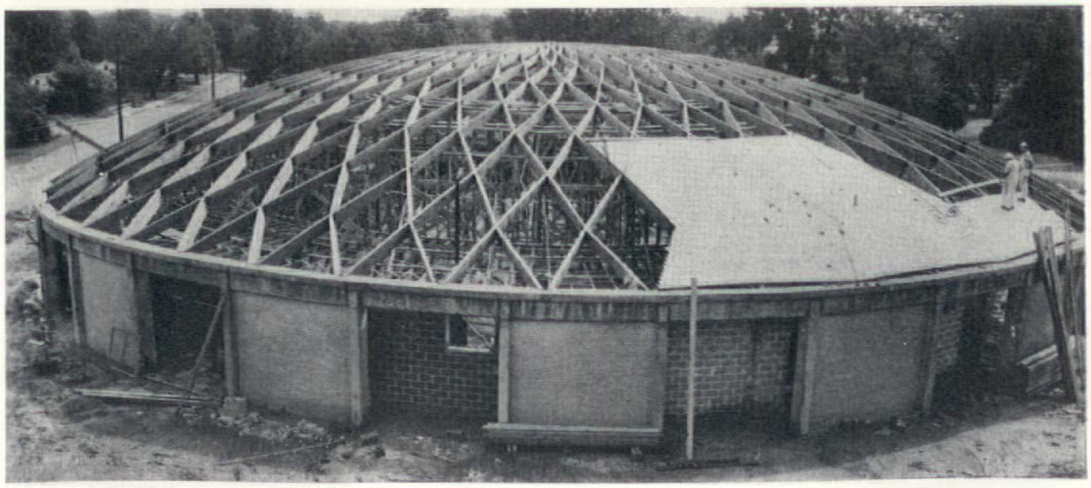

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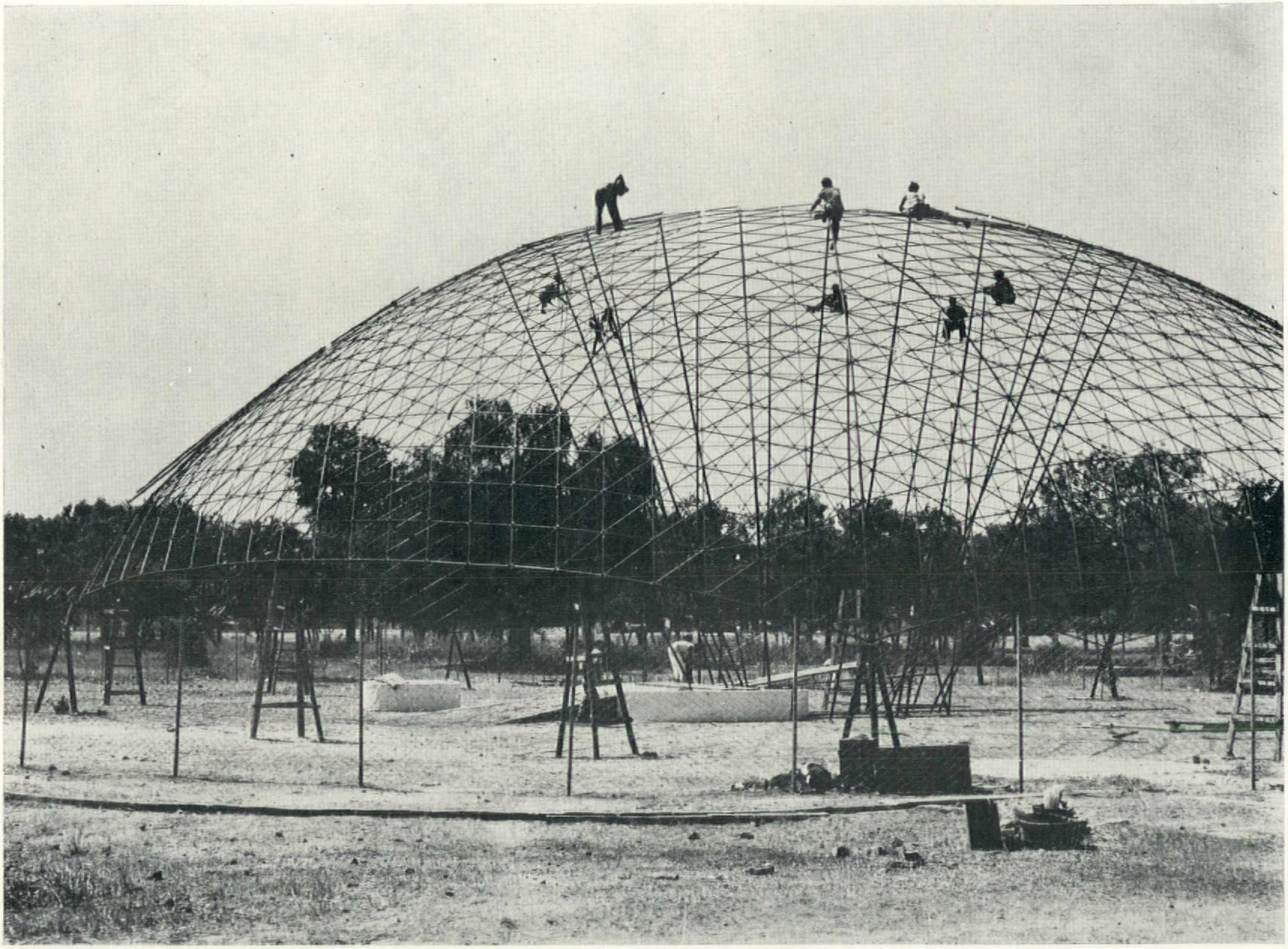

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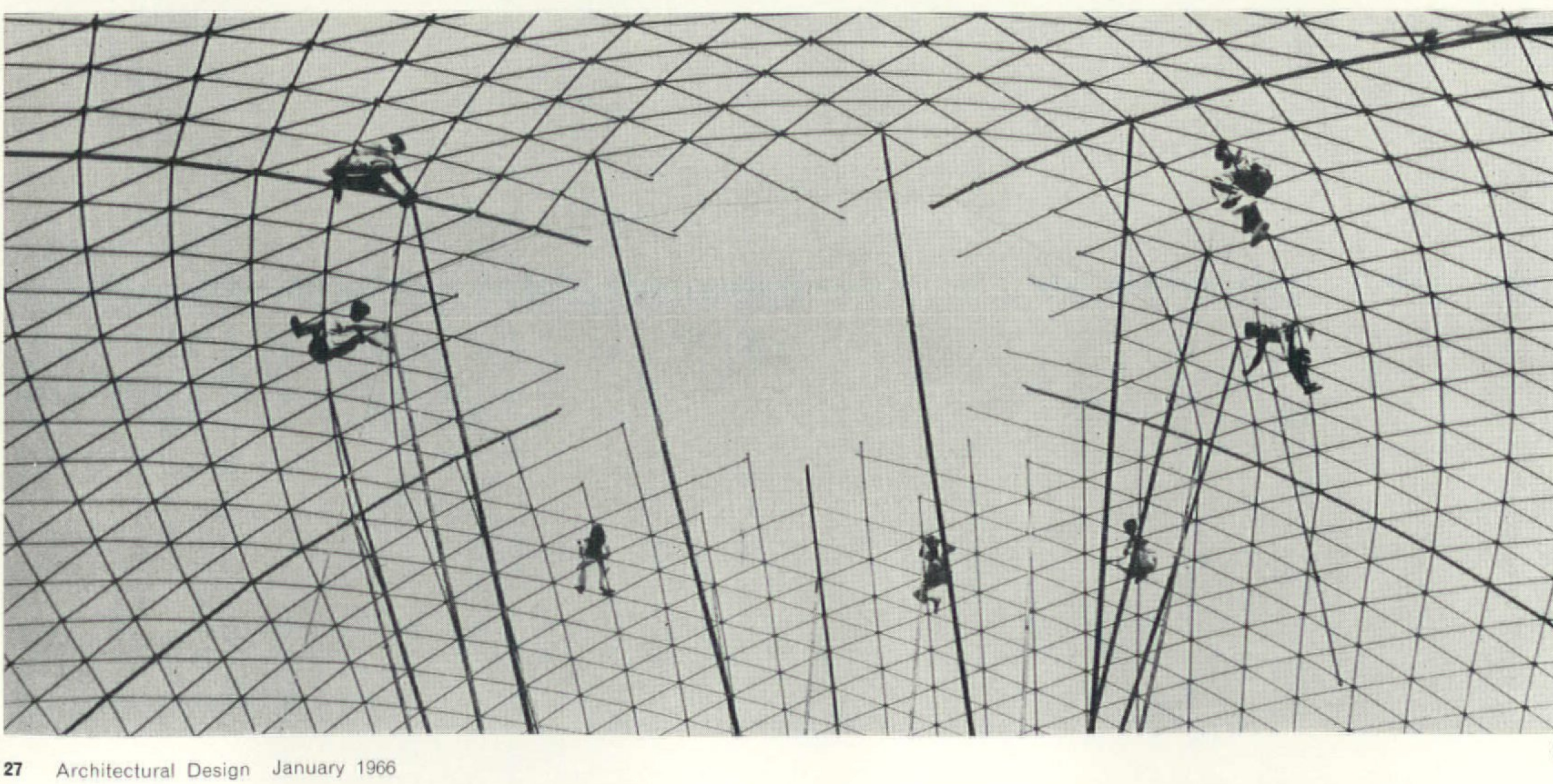

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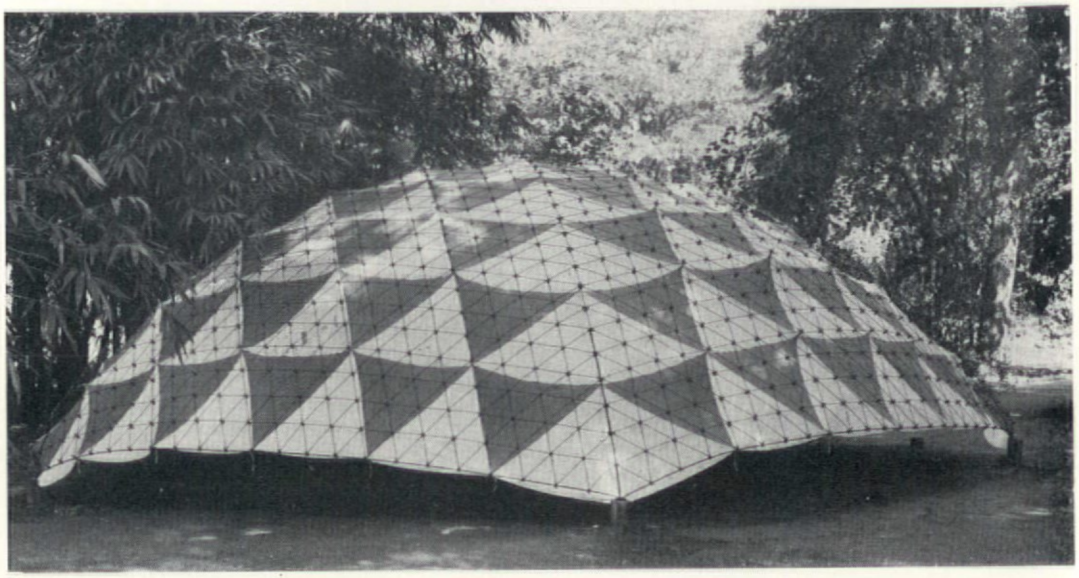
Demountable domes

Among the most engaging of light tubular domes are those designed and built in Ahmedabad by Gautam Sarabhai. Having seen Buckminster Fuller's geodesic domes he started to experiment with wire models and as a result of his studies he worked out, from first principles, an extremely economical system of bracing. In 1956, he built three models before attempting the construction of the first full-size dome. The original model was 2ft in diameter and drinking straws were used as the members. The second was a 6ft diameter dome using $\frac{1}{8}$in copper tubing. The last experimental model was 25ft across and made of $\frac{1}{8}$in steel wire **3**. The first real dome built by Sarabhai was constructed in 1956–57 for a Calicloth travelling exhibition **4**. His second dome is of an improved design. Its diameter is 100ft 6in and height only 26ft. The struts are of $\frac{3}{4}$in and 2in steel tubing. The skin is a specially treated waterproof canvas. The total length of tubing is half that of the first dome and the area of the fabric is reduced by 30 per cent. It takes only half the time to erect and dismantle.

Sarabhai's domes are completely demountable and re-usable. Each structure is no more than a truck-load. Steel tubing has been used because of the rough handling that has to be withstood in transport and during repeated erection and dismantling. The total weight of these domes (including skin) is about 0·65lb/ft^2.

The domes can withstand wind velocities up to 80 miles per hour.

In 1963 Sarabhai built a permanent all-weather stressed-skin dome for the Calicloth Shop in Ahmedabad **5**. It stands on a basement, 60ft × 60ft, covered with a three-way double-layer grid made from $\frac{3}{4}$in steel tubing and 1in struts **6**. The top and bottom layers are continuous runs of steel tubing connected together at each joint by a single bolt only. The horizontal tubes are continuous, flattened and drilled at the nodal points. The inclined diagonal members consist of short lengths of tubes having their ends suitably bent, flattened and drilled for connection.



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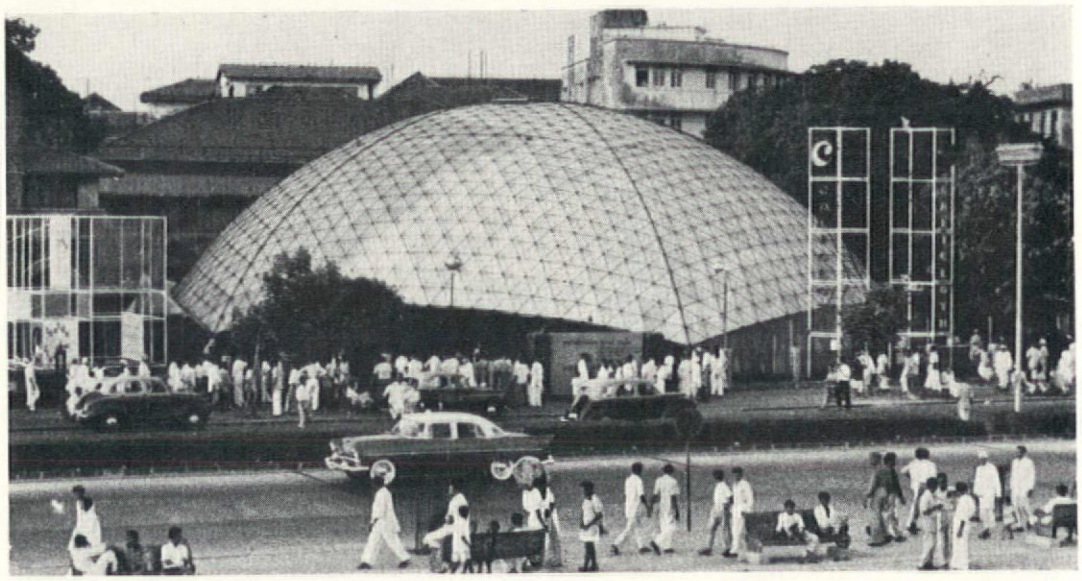

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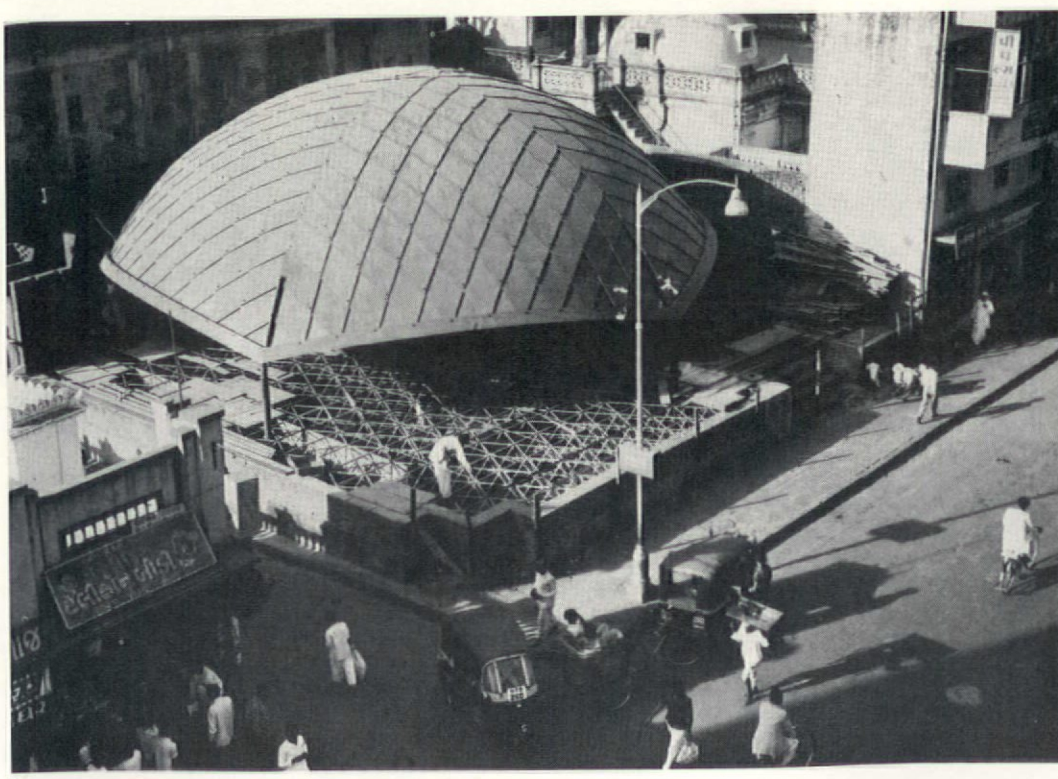

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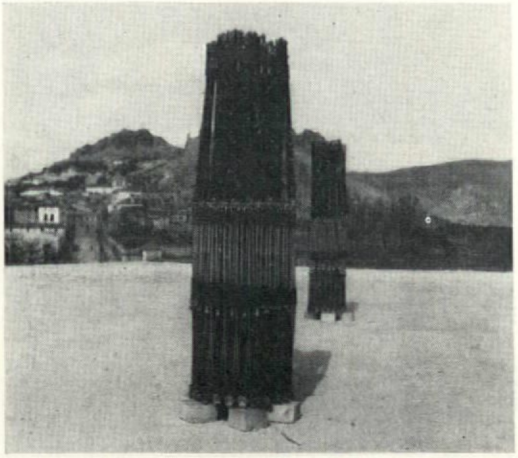
1 & 2
Erection of Calicloth travelling exhibition domes I and II. The domes are built in circular fashion spiralling into the highest point. No scaffolding is required because as the long struts are interwoven they hold themselves in position. End tubes are propped up from below while workmen clamber up to knit them together at the centre

3
Experimental dome 1956. Diameter 25ft; struts $\frac{1}{8}$in steel wire; skin, water-repellent cotton fabric

4
Calicloth travelling exhibition dome I, 1956–57. Diameter 100ft, height 37ft; struts $\frac{1}{2}$in and $1\frac{1}{2}$in steel tubing; skin, water repellent cotton fabric and polyethylene film

5
Calicloth shop, Ahmedabad, India, 1963. All-weather stressed skin dome, 50ft diameter. No struts, self-supporting overlapping $\frac{1}{2}$in waterproofed plywood



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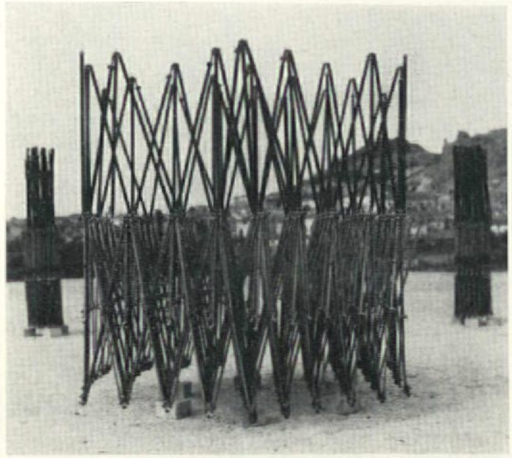

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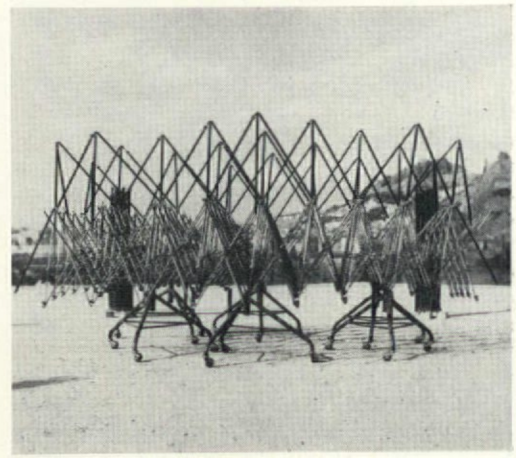

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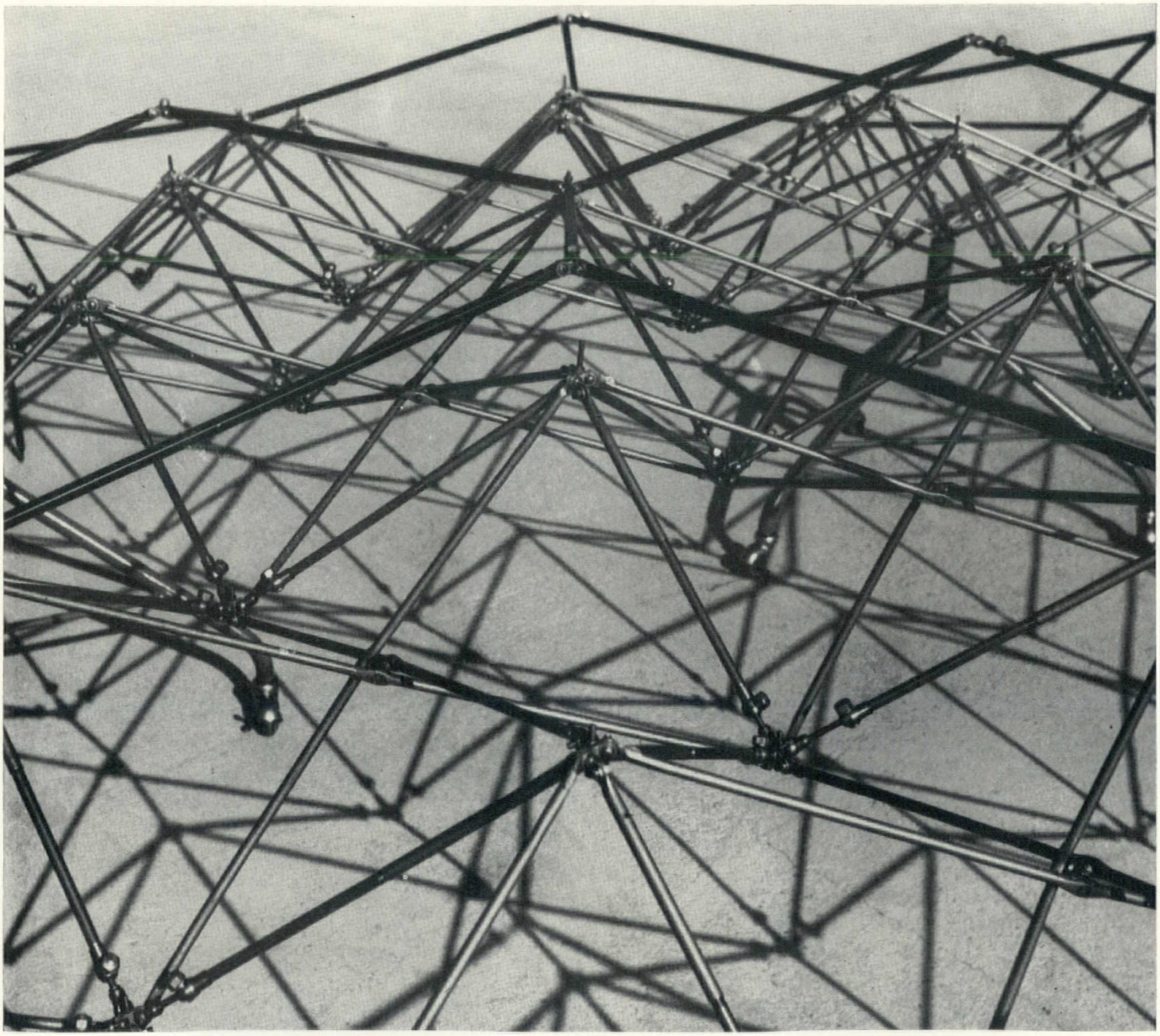

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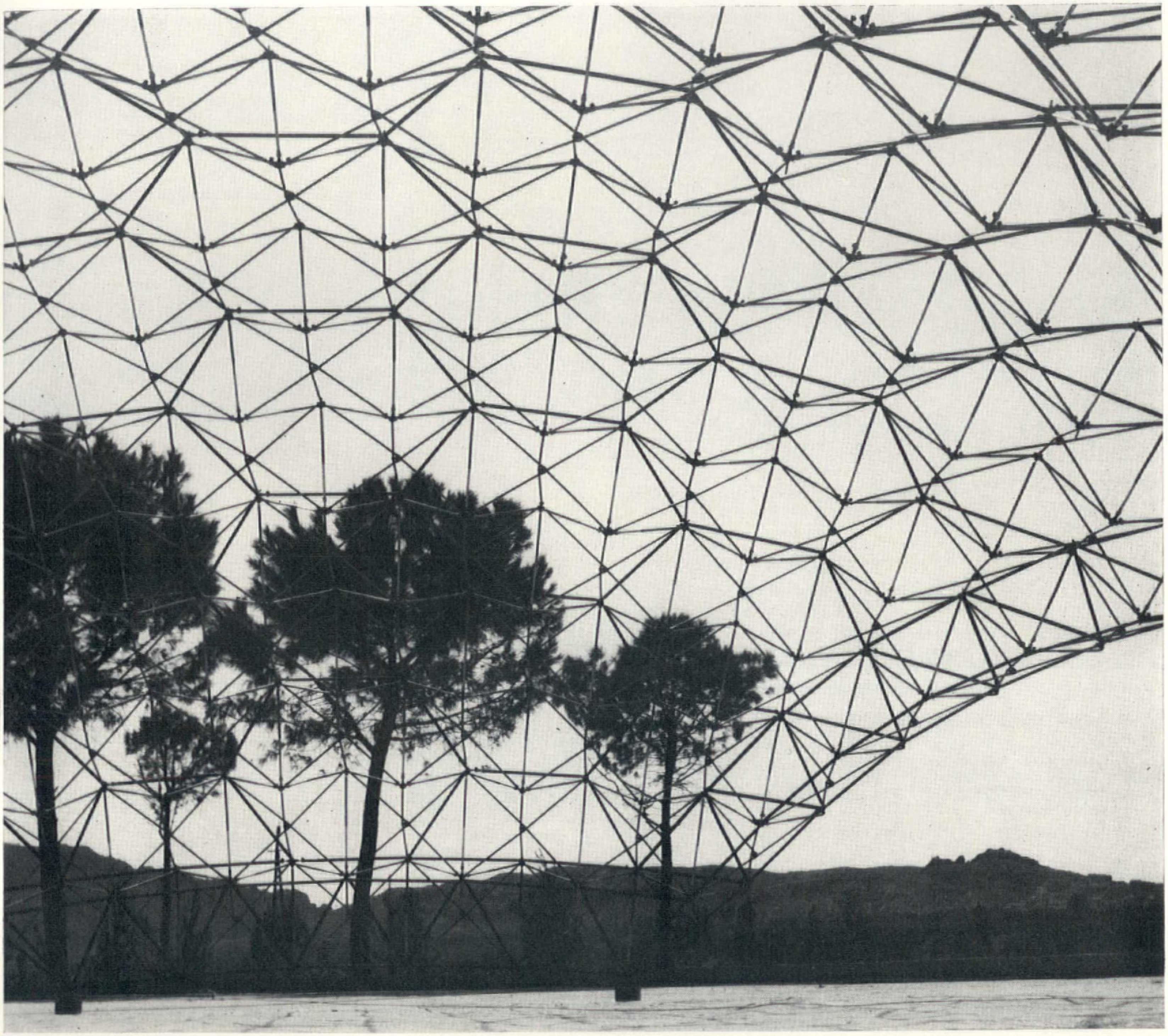

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1–6
Details and general views of a portable, expandable dome designed by the young Spaniard Emilio Pérez Piñero of Madrid. Segments are brought to the site as compact bundles. These are unfolded on wheeled trolleys and joined together to provide domed structures up to 300ft in diameter. Piñero is responsible for other equally ingenious systems of folding space frames

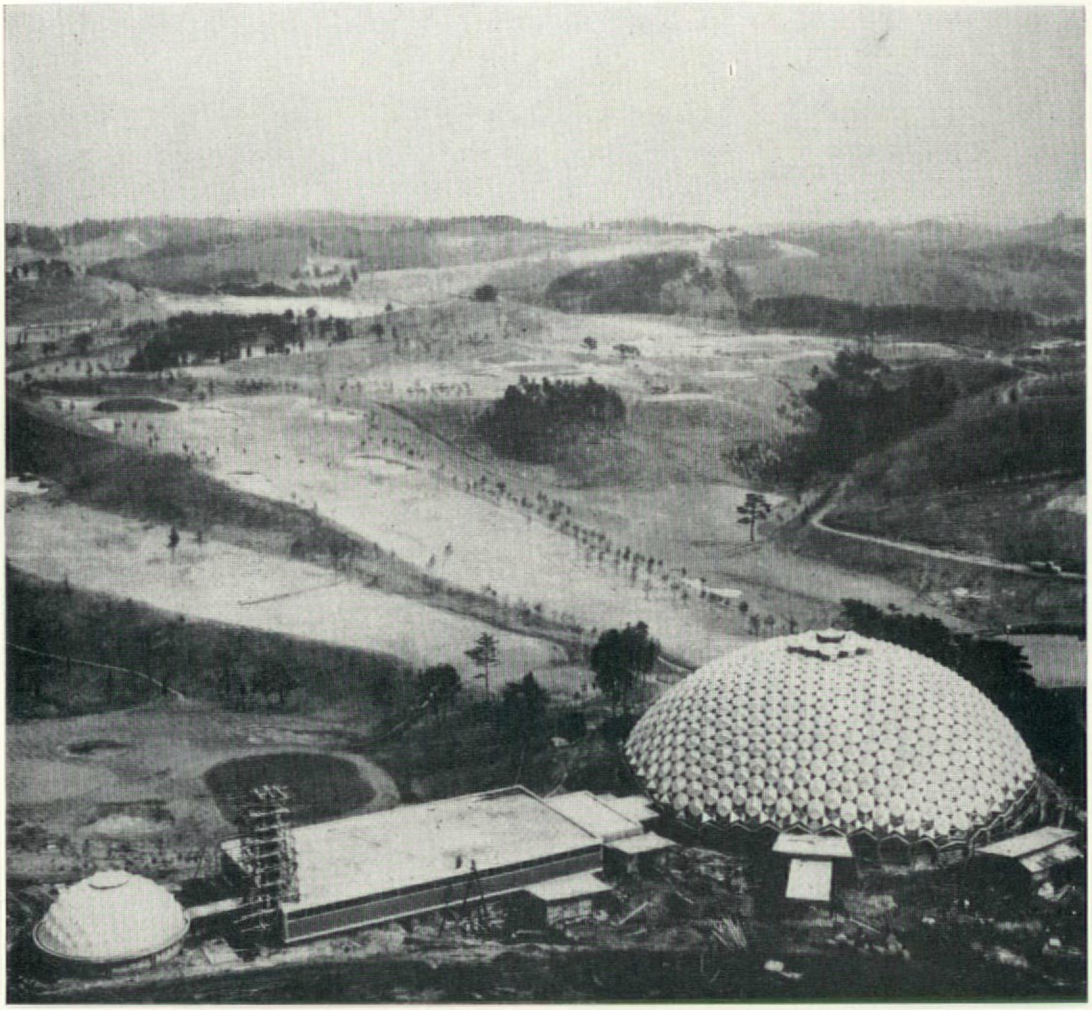
See *AD* December 1961 page 570

6

Aluminium domes

Of the many recent developments in aluminium space structures, one has to single out the activities of a Hungarian engineer, Istvan Kadar, who has built many aluminium domes of prefabricated units. His design for the Budapest Industrial Fair, 1961, was awarded a gold medal. This demountable dome, 47m in diameter, is hexagonal in plan and is built from prefabricated aluminium triangles, bolted together to form a regular spherical network. He has also constructed several double-layer grids, some of them of considerable size.

1
Tokyo country club, designed by Geometrics Incorporated in collaboration with R. Buckminster Fuller. Built by the Taisei Construction Co.
2
Tubular aluminium geodesic dome outside Mexico City. Diameter 200ft, weight 62,000lb. Built by Alcomex, a subsidiary of Alcoa
3
Aluminium dome built in the Triodetic system
4
Aluminium dome covering the Headquarters of the American Society for Metals, Cleveland. J. T. Kelly
5
An aluminium two-way grid dome during a trial erection Hamman type
6 & 7
Aluminium domes built for the Budapest Industrial Fair 1961. Designer Istvan Kadar
8
Prefabricated elements used by Istvan Kadar
9
Mannesmann aluminium dome
10
BEA aluminium dome built from prefabricated units for the British Trade Exhibition, Stockholm 1962. Space Structures Research Ltd. Analysis: Makowski
11
Baco triodetic dome structure used as a mobile exhibition pavilion. Diameter 76ft, design by Modular Metals



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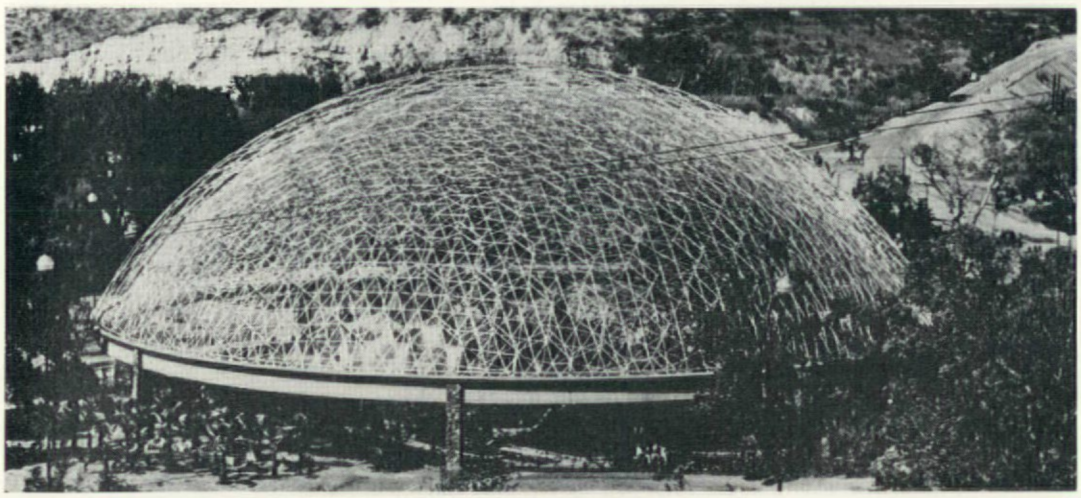

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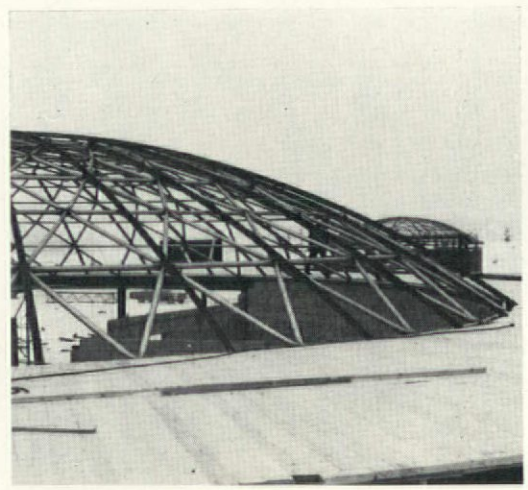

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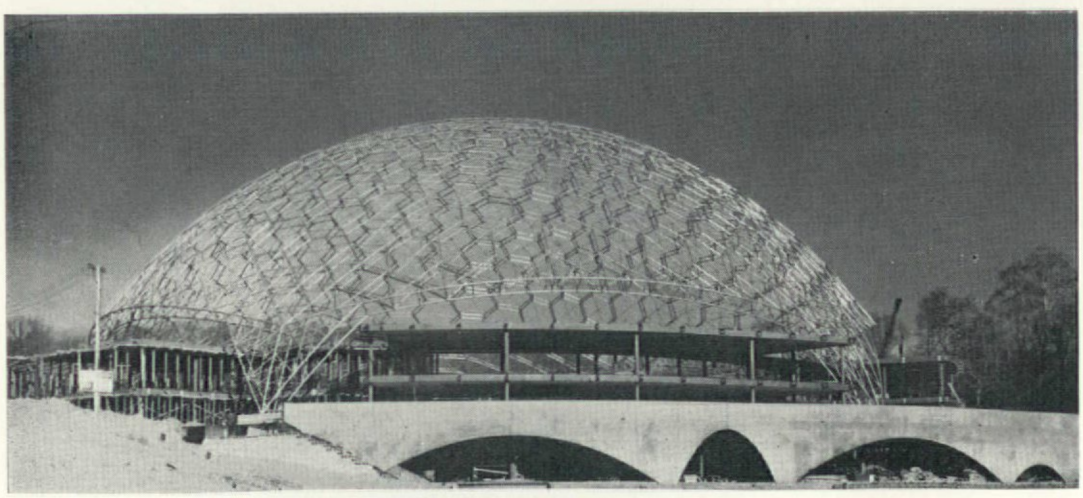

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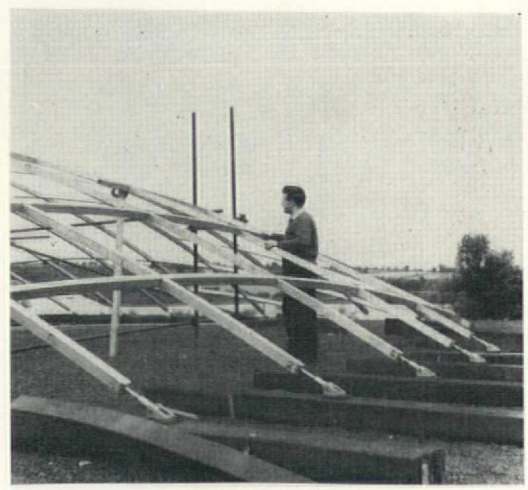

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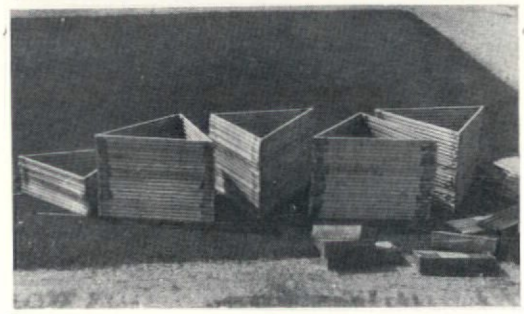

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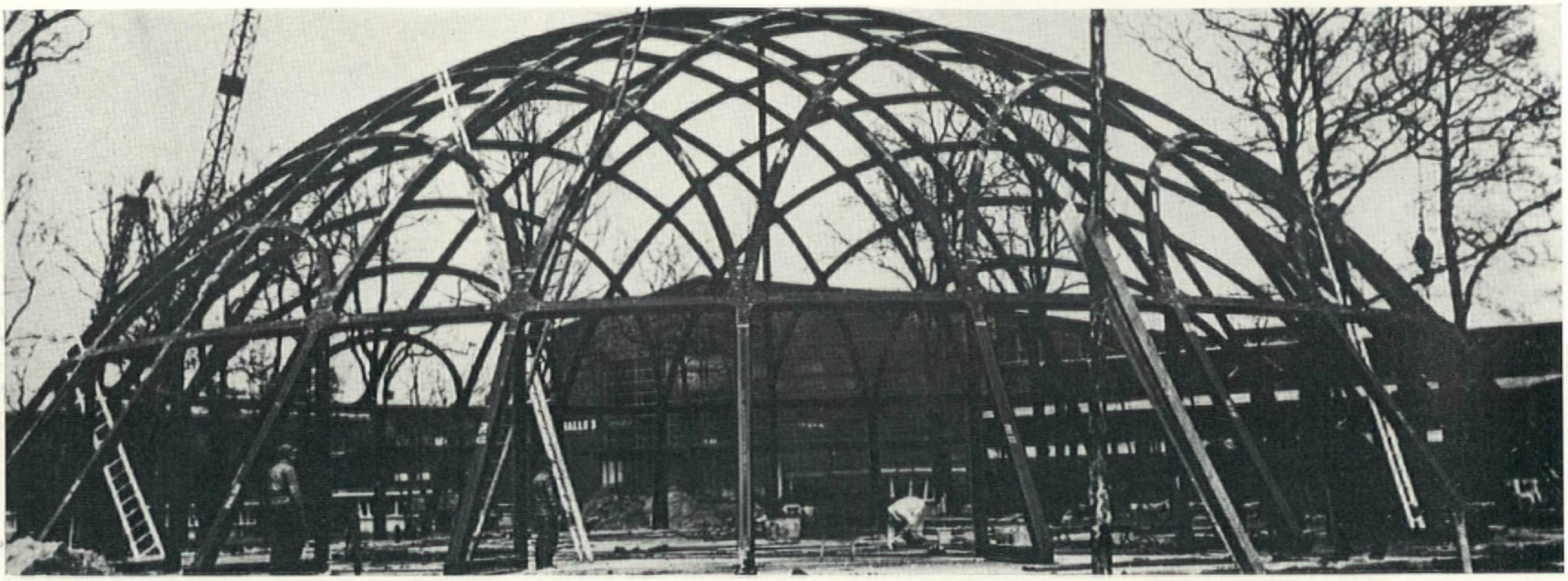

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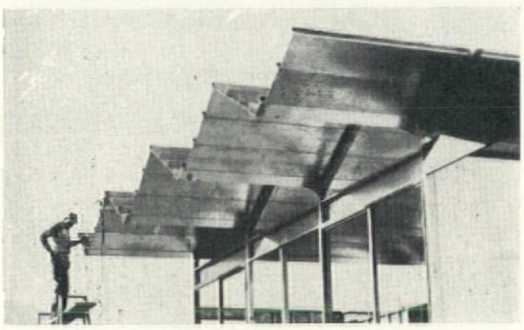


2

1
Two-way steel grid dome, Krupp Pavilion, Hanover
2
Folded plate steel roof, California, by Steelways
3 & 4
Interior and exterior of the Lightfoot Sports Centre, Newcastle upon Tyne. The laminated timber beams are 8in wide, 104ft long, with a maximum depth of 26in at their centres, tapering to 18in at the foundations and 10in at the thrust ring. Architects: Williamson, Faulkner Brown and Partners. Structural consultants: Cooper, Higgins and Partners
5
Roof of the Bristol Hotel, Lagos, 1962. All pyramids are identical units in aluminium alloy sheet
6
Aluminium space grid for the IUA building, 1961, London. Theo Crosby. Structure: Prof. Makowski
7 & 9
Tests to destruction on full-size aluminium pyramids
8
Detail of the connector used at Lagos
10
A node connector for the South Bank building
11 & 12
Pyramidal structures developed by Z. Makowski

Timber domes

The largest laminated timber braced dome in Great Britain was built in 1964 at Newcastle upon Tyne. It has an overall diameter of 206ft.

Laminated timber was used as it combined a high strength to weight ratio, ease of fabrication, transport, erection and low final cost. The laminations of the ribs are bonded with Aerodux resorcinol glue. Each rib is 104ft long and $8\frac{1}{4}$in wide, the depth varying from 26in at the centre to 18in at the base and 10in at the apex thrust ring. The consulting engineer was D. W. Cooper; the architects: Williamson, Faulkner, Brown & Partners.

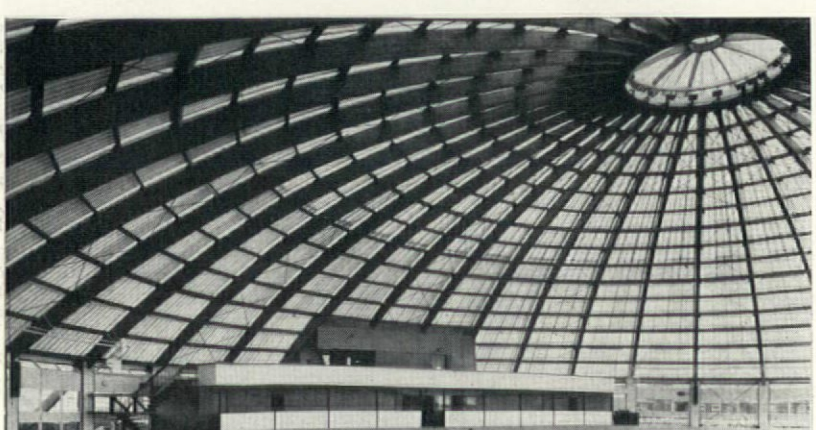
Folded plate systems

The practical difficulty of producing smooth surfaces curved in two directions has led to a greater interest in folded plate systems, which are equally interesting architecturally, but are much simpler to construct. Folded plate systems are not only of precast reinforced concrete, but also of plywood, plastics, aluminium and steel. Various interesting lattice systems have been developed using prefabricated panels, interconnected along their common edges. These structures are typical examples of stressed skin systems in which the external loading is resolved into components acting in the planes of the plates forming the structure. The components or the skin forces can be resisted very efficiently as they act in the direction of the greatest stiffness of the plate. Countless variations are possible, varying from simple repeating V systems to very complicated ones involving several plates in each unit. Such systems are known as 'space planes' and are made up of two or more diaphragms, usually triangular or polygonal which interact and support vertical loads without beams or trusses.

Structures of any layout can be covered with these systems—pitched roof-type structures, portal frames, arches, cylindrical barrel vaults and domes are of particular interest. There are various exciting possibilities for light prefabricated lattice units, which could be designed for quick erection by semi-skilled workmen.

It must be pointed out that these systems derive most of their strength from their shape—their form gives them great rigidity, making possible the very efficient use of construction materials of low Young's Modulus, such as plastics and aluminium, which in orthodox types of construction would normally lead to excessive deflections.

Significant developments have been carried out during the last five years in the construction of timber folded plate structures, mainly in the USA. Timber folded plate roofs consist of rectangular plywood-sheathed diaphragms, tilted so that the long edges are level and the short edges inclined. For large spans, the use of space-plane construction eliminates much of the heavy framing used in conventional systems. In addition, the use of prefabricated units permits closer cost control, reduction in labour cost, better control during erection on the site and less dependance on weather. Recently, several churches, meeting halls, schools and warehouses have been covered with timber folded plate roofs.



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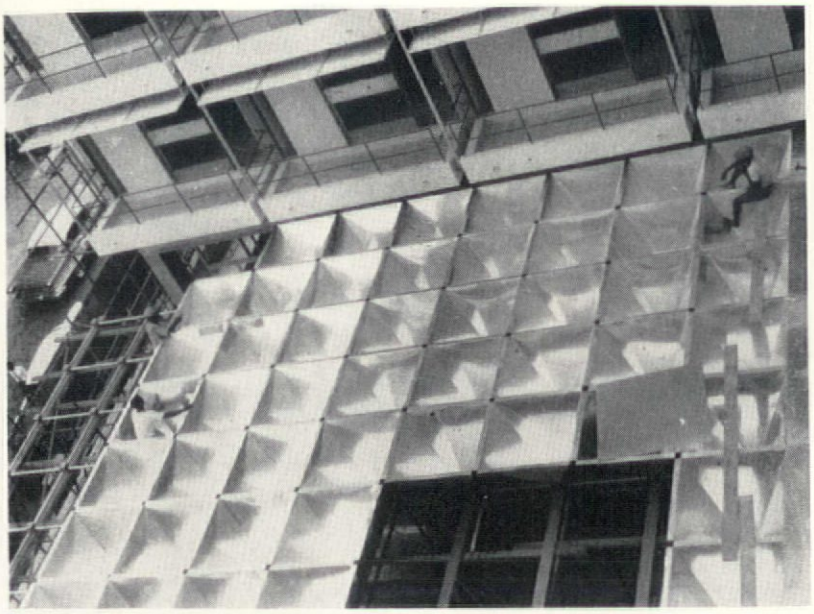

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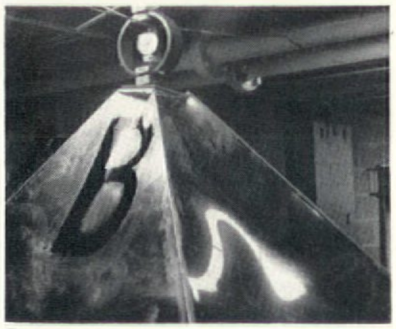

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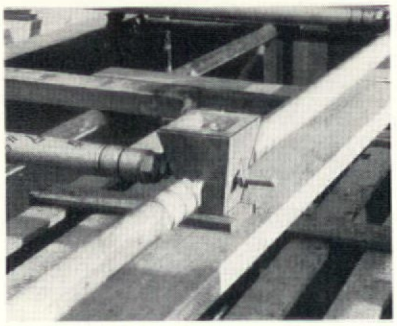

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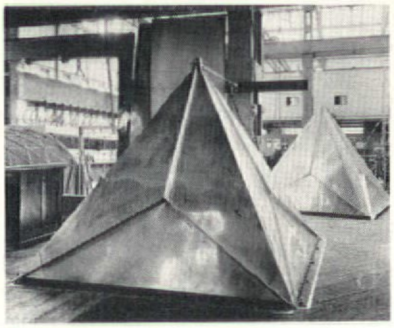

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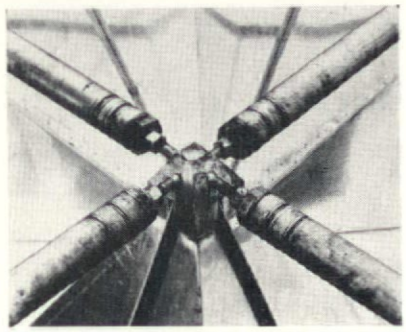

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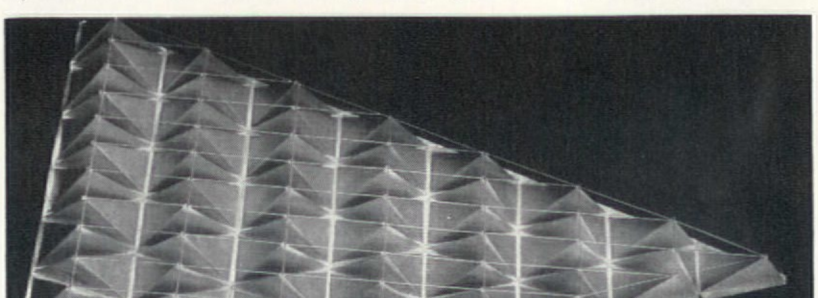
Stressed skin space grids

An interesting system of stressed skin space grids, known as 'Pyramroof' construction, has been developed by the author in collaboration with Space Structures Research Ltd. It is an extension and an improvement of the more usual type of double-layer space grid. 'Pyramroof' construction is a stressed sheet space system which combines great structural efficiency with all the possible advantages of prefabrication. Stressed sheet space grids consist of a large number of prefabricated three-dimensional units, made from these sheets inter-connected along the edges and arranged in regular geometrical patterns. The superiority of stressed skin space structures over the double-layer grids of the skeleton type lies in the fact that whereas the former require a separate roof decking, which as a rule does not contribute to the overall stiffness of the system, in the case of a sheet structure such decking can be provided by the sheets themselves acting not only as a roof covering, but also as a load-bearing part of the structure. It has been proved also that in the case of skeleton space systems, their overall strength is governed by the buckling of the compression members. In the case of stressed skin sheet space structures, the compression edges of the sheet units receive additional lateral restraint from the adjacent sheets, thus effectively preventing their tendency to buckle. This increases considerably the load carrying capacity of the whole system.

The first commercial application of the 'Pyramroof' is the roof covering a restaurant in the Bristol Hotel, Lagos, in Nigeria. It covers an area of 52ft × 48ft and consists of 150 inverted pyramids made in thin aluminium sheeting. Each pyramid is 4ft × 4ft at the base and 3ft 6in high. The whole roof is supported by only four columns. Another equally interesting structure, also designed by the author, and built in this system, was the roof over the headquarters building by Theo Crosby for the 1961 Congress of the International Union of Architects in London. This roof consisted of 132 prefabricated sheet pyramids. These pyramids were identical in dimensions and were 8ft × 8ft at the base and 7ft high, covering an area of 160ft × 64ft. These structures made a considerable impact and since their erection several similar aluminium sheet space systems have been built in Europe and the USA.

The stress distribution in the stressed skin space grids is primarily of the membrane type with virtual elimination of bending stresses. The great rigidity of the aluminium pyramidal structures became apparent during laboratory tests on large-size specimens. This encouraged the experimental investigation of plastics pyramidal systems. Tests carried out by the author and his research students, D. Robak and R. Gilkie at the Structural Plastics Research Unit, Battersea College, on such structures, have revealed that plastics pyramidal units have a surprisingly high load carrying capacity.



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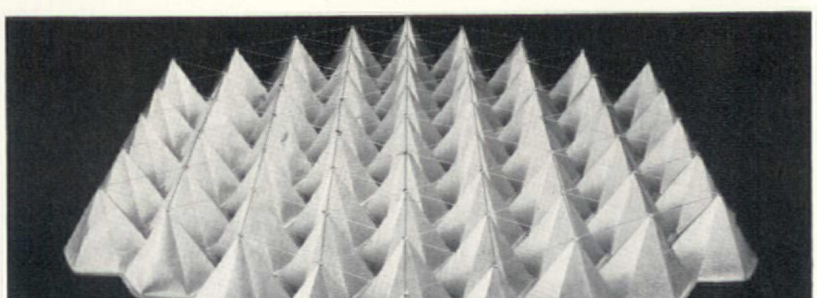

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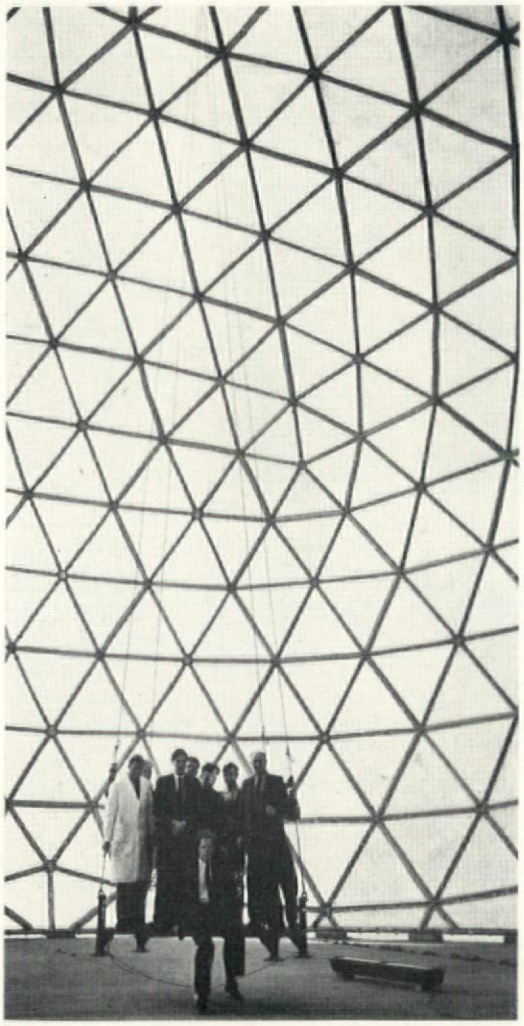
Plastics space structures

Considerable progress has been made in the structural applications of plastics. Unlike conventional materials, plastics exhibit the unusual feature of combining various desirable properties at the same time, e.g. light weight, strength, translucency and corrosion resistance. Their strength to weight ratio is higher than for most metals. Their resistance to corrosion and wear is outstanding. Their ease of formability makes them very adaptable for production line and factory assembly methods. If used merely as a direct replacement for other materials, plastics may prove to be more expensive, but if applied in an intelligent way in shapes appropriate to their characteristics, the unique properties of plastics may lead to highly efficient and economical solutions. The use of plastics in structural applications may develop entirely new products whose shapes and appearances may differ appreciably from those already accepted by the general public. The limiting factor in the design of plastics structures is stiffness rather than strength, but the lack of stiffness in plastics can be effectively overcome by the proper choice of structural form.

Stressed-skin structures demonstrate convincingly that their strength is primarily a function of the geometry of the structure, i.e. of the configuration of the interconnected units, and depends only to a limited extent upon the properties of the material of which they are made.

Space structures of the stressed skin type are a field of largely unexplored possibilities for the structural use of plastics. Many experimental plastics space structures have been built during the last decade in various countries. Research proved that

1. It is feasible to design and construct large structures made from plastics materials which will perform their engineering functions in a satisfactory manner.



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1 & 2
Interior and exterior of an all-plastics radome built by the English Electric Co. Ltd

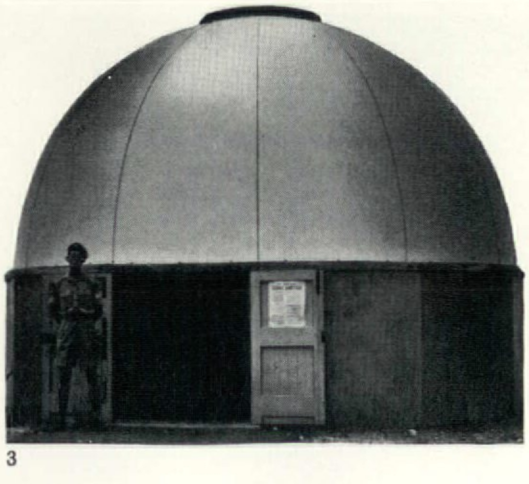
3
One of the earliest plastics radomes built in Great Britain by C. F. Taylor (Plastics) Ltd

4
An 'English Electric' Unidome, 26ft in diameter

5 & 6
Interior and exterior of an all-plastics umbrella roof structure over a market in Fresnes, France

7
Interior of a plastics garden shelter at Strathcona Park, Canada

8
Main types of plastics radomes



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2. The mechanical properties of plastics materials can be defined by the same engineering concepts as are applied to the standard materials of construction.
3. The engineering design of structures made from plastics materials can be accomplished by the same engineering principles as are applied to structures made of standard materials of construction.

The most spectacular use of plastics as main load-carrying structural material for space structures is provided by the plastic domes, especially the radomes, built in many countries during the last few years, and these examples stress the particular adaptability of plastics. Many industrial firms have already gained a considerable amount of practical experience in the production of all-plastic domes.

After the dramatic use of translucent polyester fibreglass umbrellas designed for the American Exhibition in Moscow in 1959, another equally exciting design in fibreglass reinforced plastics was tried two years ago in France, where a market in Fresnes was covered with 18 large size interconnected plastics umbrellas.

Due to the low-bearing strength of the ground, use of steel or concrete was ruled out, and construction was possible because of the light weight of the plastics. Certain parts of the umbrellas were translucent, transmitting light to the interior of the building. A very similar technique was used by the same firm, Société des Chantiers Réunis Loire-Normandie, for a second market in Ivry, built last year. Each vault is made up of four elements resting on a central column which is also made of plastics. Elements were bolted together, two by two, on the ground, and the half-vaults made in this way were raised by a small crane and placed on the columns. It is interesting to note that in 1965, also in France, another large market in Epinay-sur-Seine was covered by prefabricated glass fibre reinforced plastics roof consisting of folded plate elements. The result, architecturally and structurally, is most satisfying.

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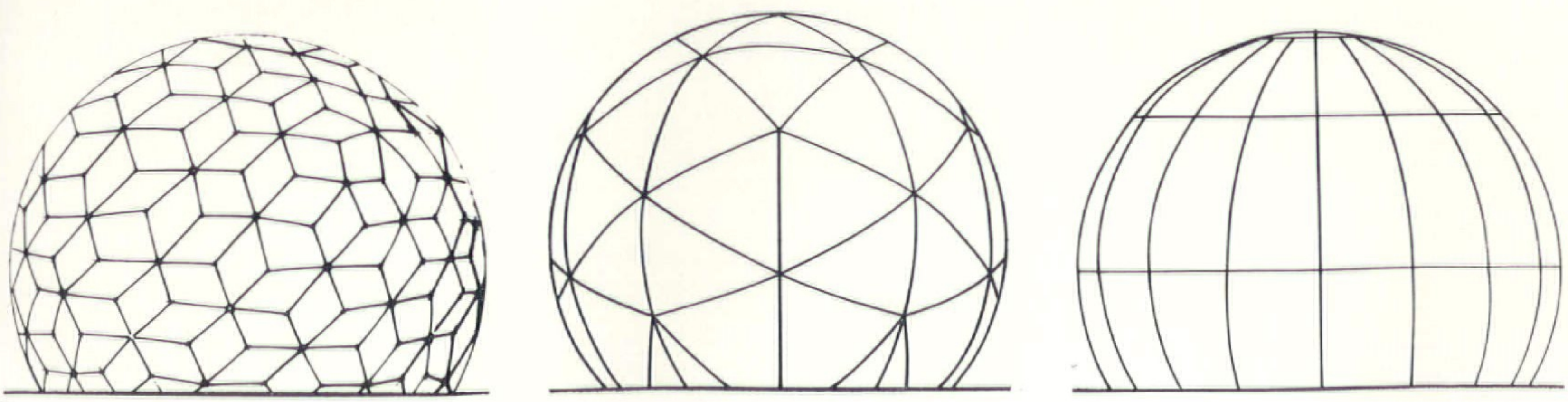

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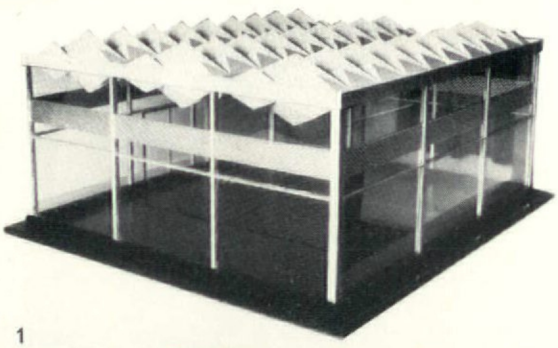

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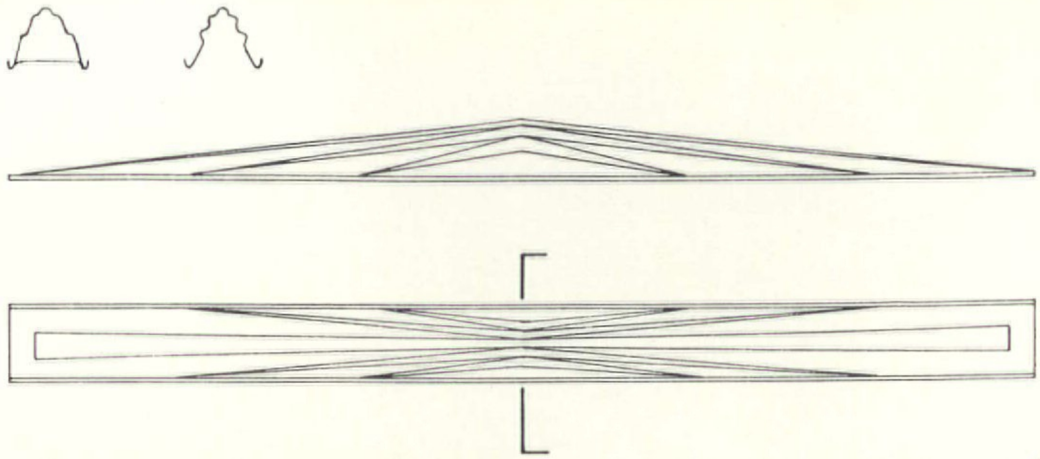

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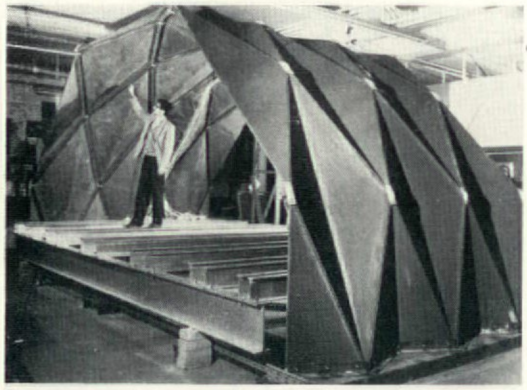

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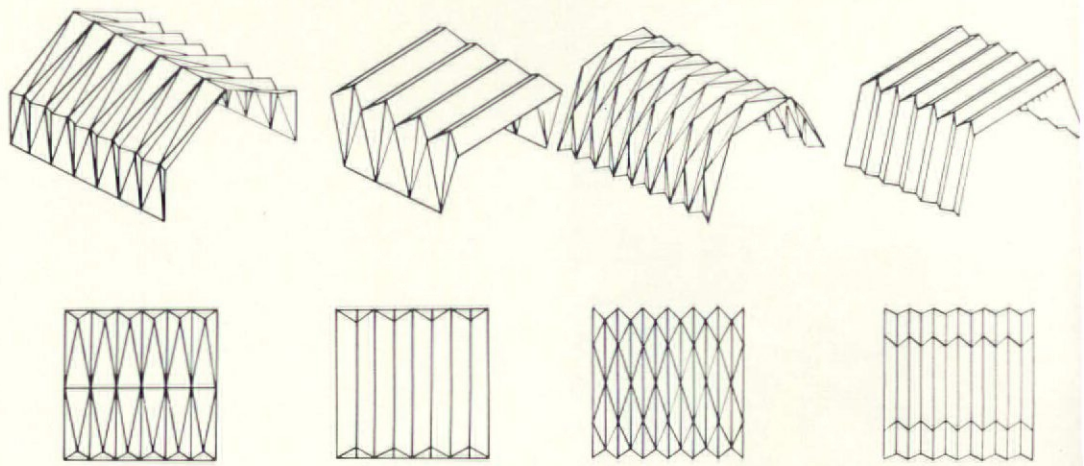

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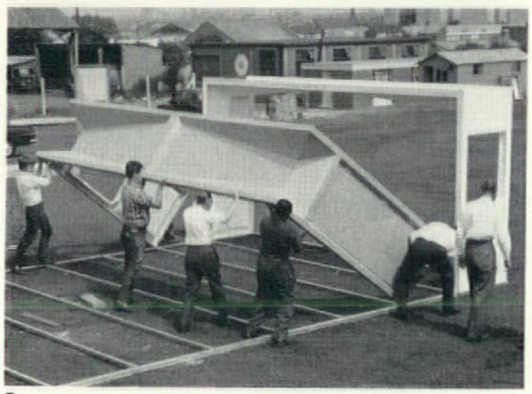

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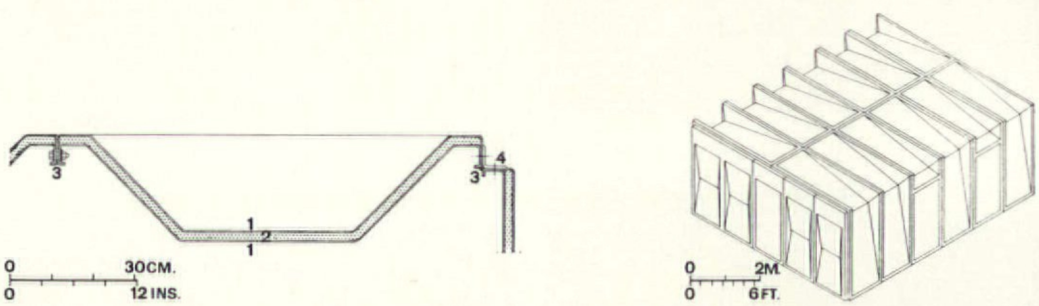

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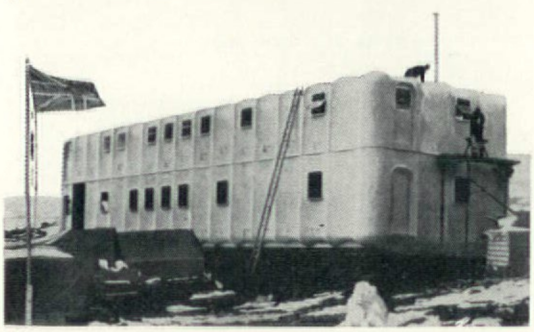

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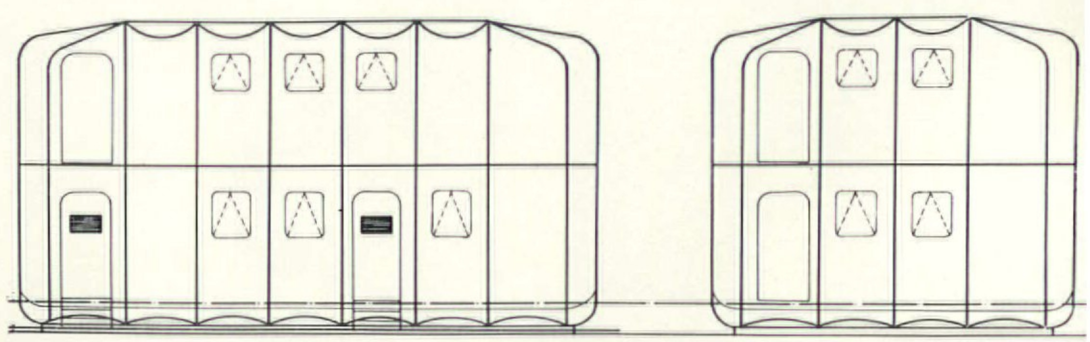

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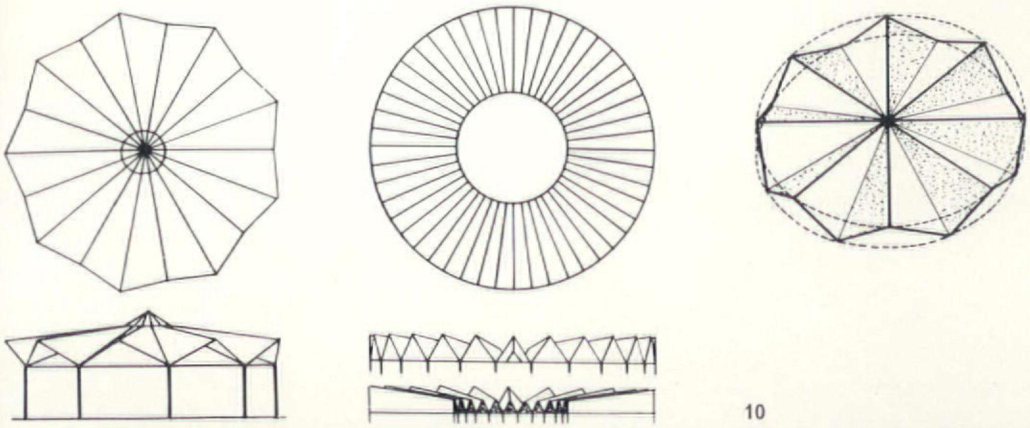
Plastics folded plate roof, Mickleover Transport Ltd.
2
Cross-sections, elevation and plan of a 38ft prefabricated glass reinforced plastics units used for a garden canopy in Houston. Weight 240lb
3
All-plastics barrel vault built at Battersea College
4
Principle types of folded plate barrel vaults
5 & 6
Erection and roof details of an all-plastics prefabricated building in the Clamp system developed by James Dartford, produced by Mickleover Transport Ltd.
1 $\frac{1}{8}$in polyester-glass outer skins, self extinguishing
2 $\frac{3}{4}$in expanded phenolid foam core
3 weather seal 4 m.s. angle stop
7 & 8
Plastics prefabricated buildings built for Bakelite by Mickleover Transport Ltd.
9
Circular folded plate structures in plastics
10
Lifting up of a 24ft diameter folded plate plastics roof for a hall of the Hylton Red House. Webster Davidson
11 & 12
Prefabricated glass reinforced polyester resin roof modular units developed in Italy
13
Transport of the prefabricated roof units shown in 12

Current trends put a special emphasis on membranal structures in which bending is either minimized or eliminated entirely. A typical example is a hyperbolic paraboloid. Several all-plastics hyperbolic paraboloids have been constructed during the recent years in the USA and Canada. Although chronologically the development of plastics structures in Great Britain has been, perhaps, late in comparison with those in other countries, the practical achievements in the field of all-plastics space structures are much more pronounced here than in many other countries. This is mainly because of the activities of the London firm of Mickleover Transport Ltd. This progressive firm has been actively engaged on an intensive evaluation of the potential for plastics in structural applications. During the last few years they have built many all-plastics space structures. They have developed special folded-plate roof components of large dimensions. Several structures were put up in 1965 using this system. The most encouraging thing is that the cost of these truly all-plastics structures has proved to be only marginally higher than that of similar structures built in conventional materials.

Of many recent developments in Italy, mention must be made of the highly successful design of modular roof sections for houses and industrial



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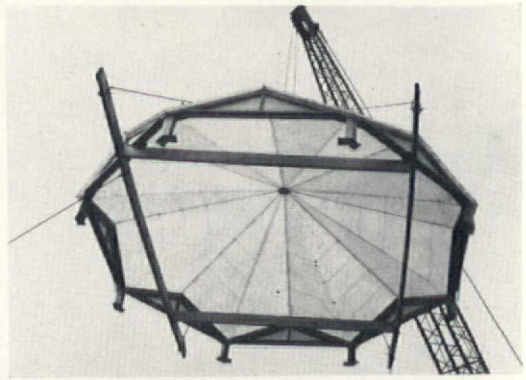

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buildings made by Resine Prodotti Derivati of Milan. This firm has developed prefabricated modular roof sections of glass fibre reinforced polyester filled with expanded polystyrene for insulation. The structure is a typical example of a plastics folded plate system. The triangular pieces weigh 300kg each. A pair of them covers an area of 20m². These roofs have been used on a number of low-rise building projects in Italy and in Switzerland.

With the growing interest in structural applications in plastics and an urgent need for the formulation of design requirements various universities are pursuing active research projects on structural plastics. In Great Britain, the Department of Civil Engineering of the Battersea College of Technology has established a Structural Plastics Research Unit. At present the research work at Battersea is concentrated on the analytical and experimental determination of stress distribution in plastic folded plate systems and in pyramidal structures. Recent tests on a full-size barrel vault consisting of prefabricated plastics units of diamond shape have proved the remarkable strength and adequate rigidity of this form of construction under various types of loading and have verified the mathematical analysis developed.

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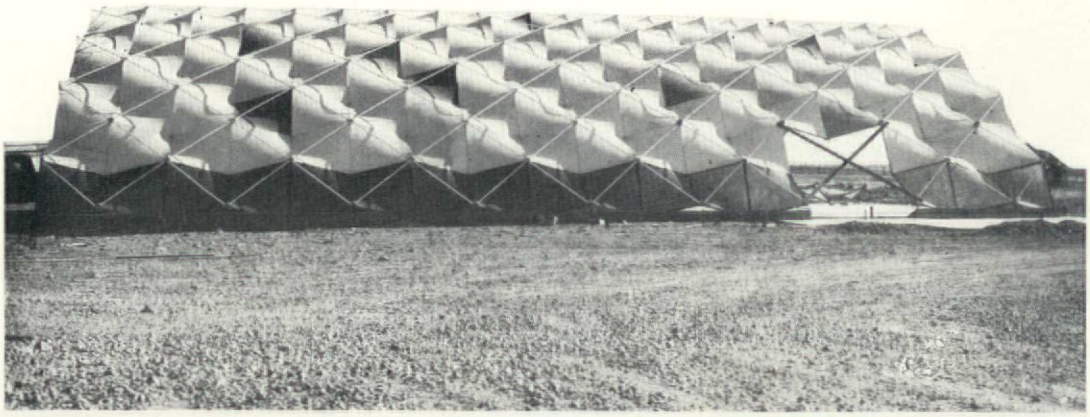

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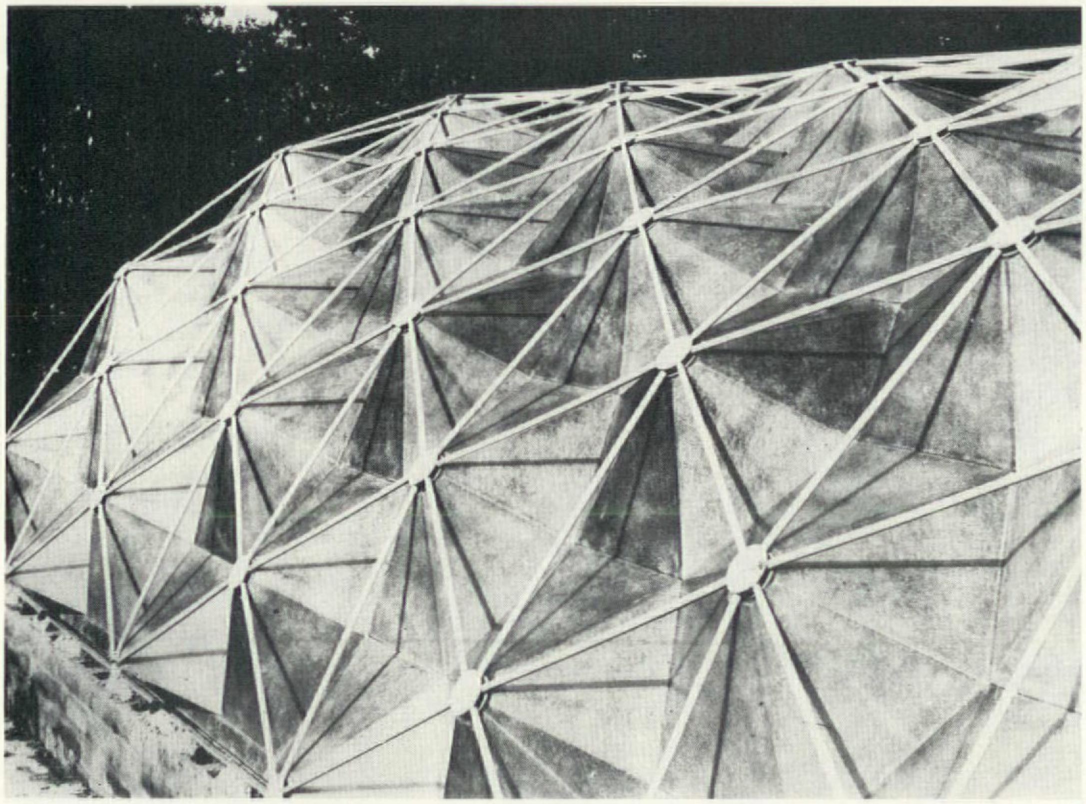

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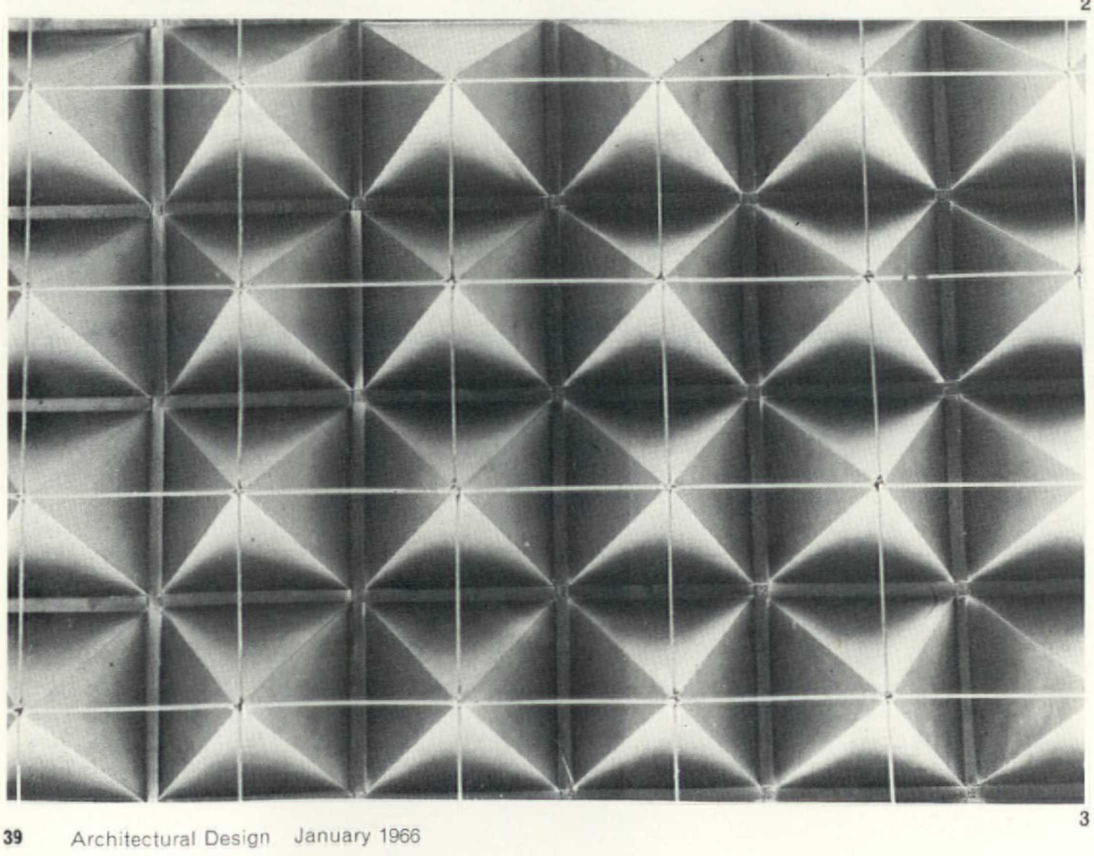

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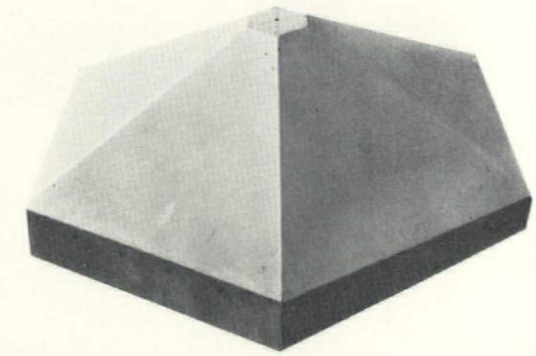

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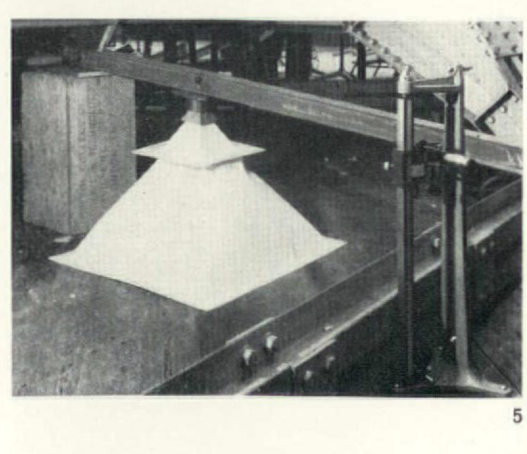
A most interesting concept is the idea of using plastic sheet pyramids for the construction of double-layer stressed-skin grid systems. These systems consist of a large number of prefabricated three-dimensional units, made in thin sheets, interconnected along the edges and arranged in regular geometrical patterns. They possess several advantages. The stress distribution is of the membrane type eliminating bending moments. The modular design makes erection exceptionally simple. The pyramidal structures, in addition possess remarkable acoustic advantages, acting as sound baffles, to reduce the noise level in the interior.

At the present time an investigation is being made at Battersea into the behaviour of barrel vaults of prefabricated plastics shallow pyramids of hexagonal shape, bolted together along the edges and stiffened at the upper layer by a three-way grid of light aluminium tubes. Interesting research work on the structural use of plastics foam in three-dimensional structures is being carried out by the Plastics Development and Service Department of the Dow Chemical Co., Midland, Michigan, USA. The company has developed an ingenious system known as 'Spiral Generation' by which single or doubly curved structures of rigid plastic foam can be built. Several all-plastics domes have been erected using this system and the results indicate significant reduction in construction time and also in building costs. The 'Spiral Generation' method involves the use of a specially designed machine which bends, places and bonds pieces of plastics foam boards together into a predetermined shape. The structures built so far have been constructed using extruded polystyrene foam as the structural material, but the Dow Company are also working on other plastic materials, including polyurethane foams. All-plastic domes up to 25m diameter have been built by 'Spiral Generation'

The erection is by a specially developed machine located in the centre of the base of the structure to be built. In building a dome, the



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Plastics barrel vault, 78ft clear span, Texas, USA. Structural Plastics Inc.
2
Plastics structure over a swimming pool at Mill Hill, C. F. Taylor (Plastics) Ltd.
3
Roof structure consisting of pyramidal units
4
Glass-reinforced modular pyramidal unit
5
Testing of PVC pyramidal units
6 & 7
Plastic house designed by Rudolf Doernach
8
Erection of a dome from plastics planks showing equipment bonding the Styrofoam boards together
9
Model of plastics houses by Giordano Forti
10
Cores used in plastics sandwich panels


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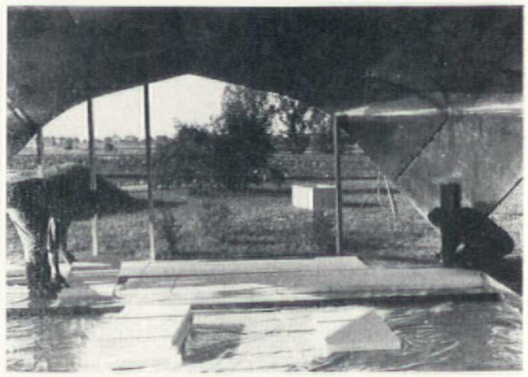
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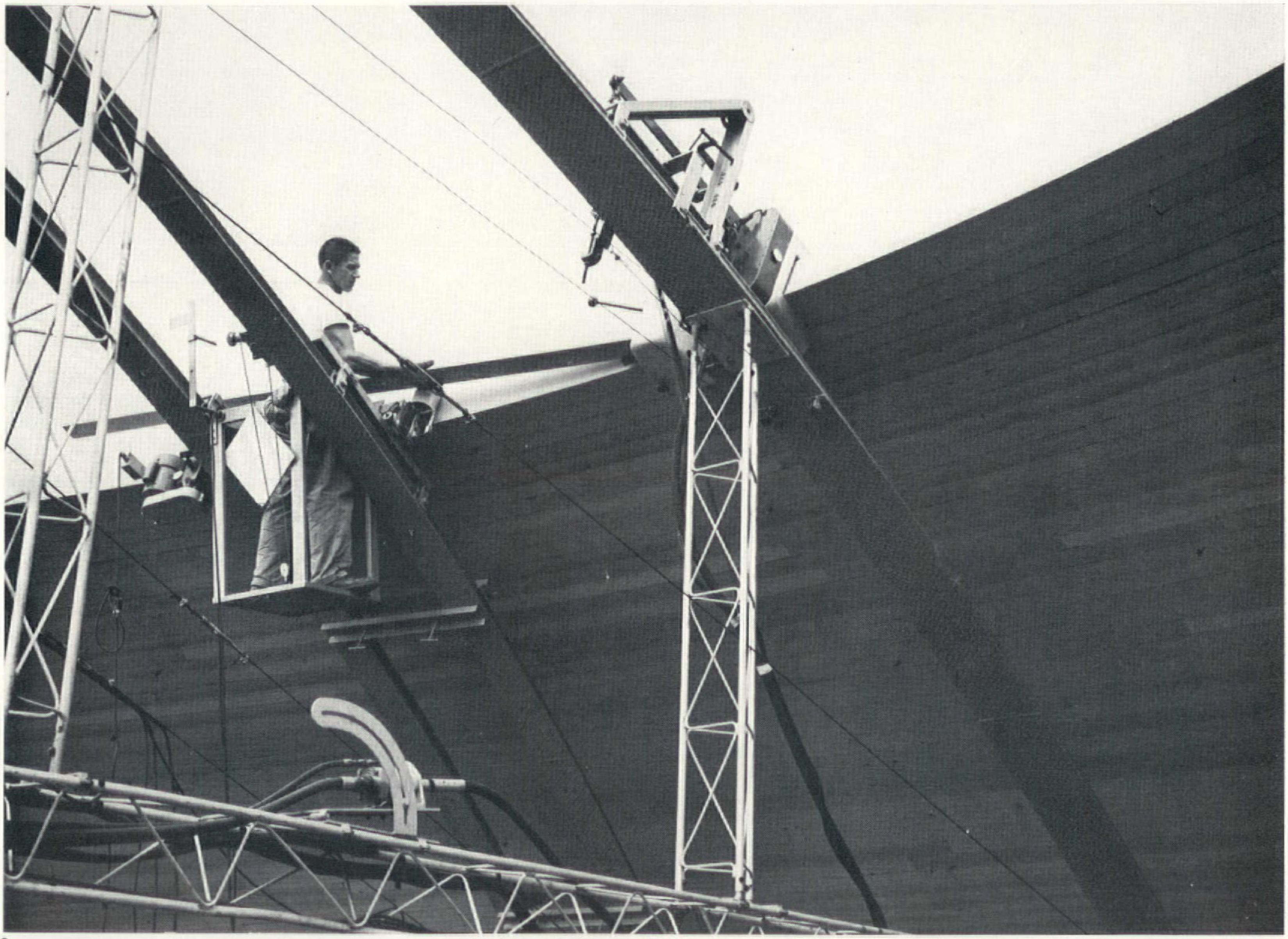
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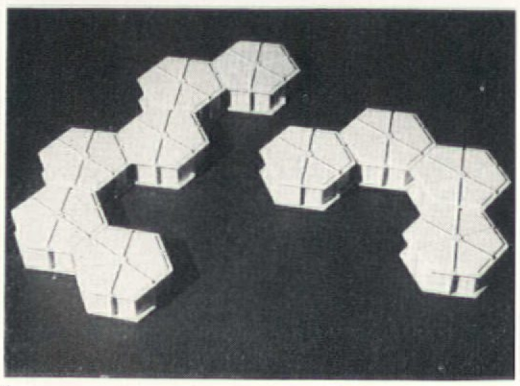
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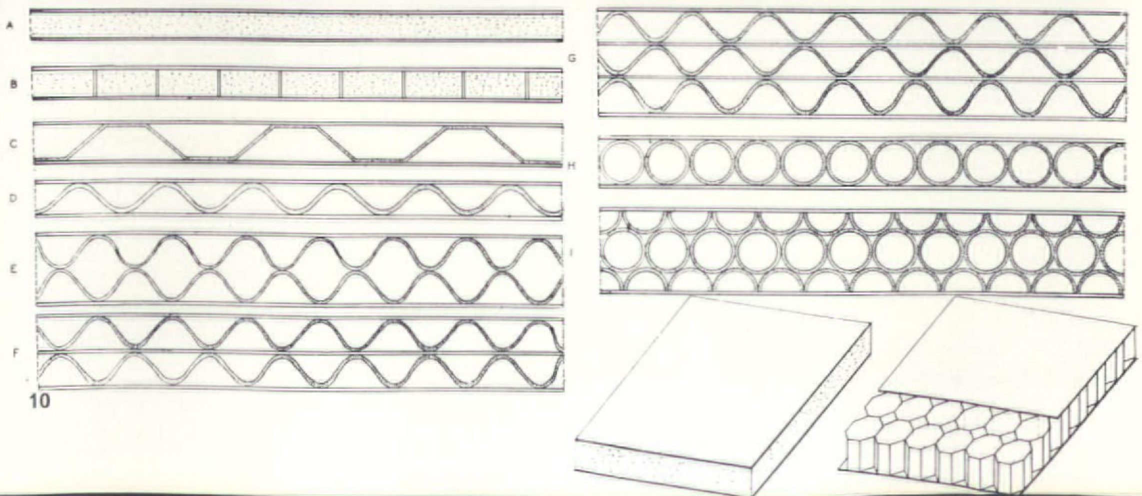

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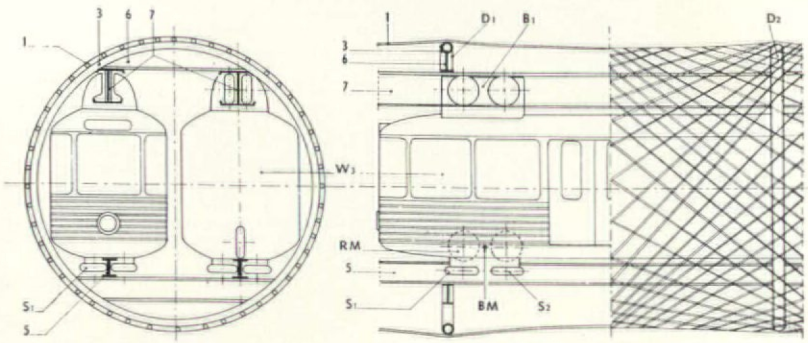


2

machine head is mounted on a boom which swings around a pivot, laying and thermally bonding layer upon layer of foam board in a rising spherical form.

Interesting work is also being carried out on plastic foams by Professors Crandall, Oberdick and Paraskevopoulos at the Architectural Research Laboratory, University of Michigan.

Conclusion

What does the future hold for space structures? Further developments, new structural forms, improved techniques of erection, improved materials, use of plastics—all these will lead to an even greater acceleration of progress in the use of space frames.

It is difficult to predict what will be the new forms. One should, perhaps, refer to the work of Robert Le Ricolais who has spent most of his life studying the evolution of three-dimensional structures. He first drew the attention of engineers to the advantages of double-layer grids and contributed so much to their present widespread use and popularity.

He is now working on a topological approach for structures and especially on funicular networks of revolution. These systems consist of simple external pretensioned networks spun around circular diaphragms, having the pretensioned thrust balanced by an axial compression member. According to Le Ricolais, the funicular networks can be the determinants of entirely new architectural forms, free from the straight jacket of the past. Tests on models have proved that such space systems have exceptional rigidity, are highly economical in the consumption of material and are suitable for covering very large spans. As a practical application of these ideas, Le Ricolais prepared a design of the Sky Rail System or Aerial Mass Transit System of high altitude consisting of high station towers interconnected by a system of bridges having their framework constructed as a tubular network.

Whatever the material in structures of the future, one thing is certain: more and more use will be made of three-dimensional systems. These will stay with us. Space structures are not a passing fashion and in the foregoing notes it has been possible to refer to only a few of the interesting three-dimensional structures that now exist or are planned for the years ahead.

1
A model of a funicular network by R. Le Ricolais

2
Sections of R. Le Ricolais' proposed Sky Rail

3
Plastic structure supported on arches of high pressure inflated plastic hose. Frankenstein and Sons Ltd.

4, 5 & 6
Air supported plastic structures. Frankenstein and Sons

7
The largest of a series of plastic structures, suitable for hangars and workshops, supported on ribs of high pressure hose (100 psi). The Walter Kidde Co. Ltd.

8
Plastics inflated airhouse developed by Storeys of Lancaster for the Hungarian Ministry of Food

9
Airhouse by Pakamac

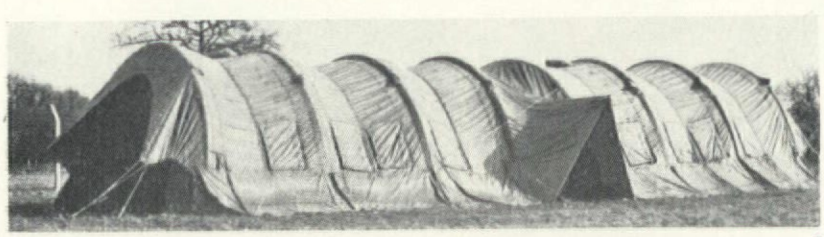
10
A 40ft diameter inflated radome. P. Frankenstein

11
Plastics airhouse produced by Kruppsbaubetriebe, Germany

12
Inflated plastic airhouse. Gourock Ropework Co. Ltd.

13
Rigid foam house. A lightweight fabric balloon in the shape of a Nissen hut is inflated, sprayed inside and outside with a liquid which immediately turns into a rigid low density foam. The finished house has great strength, it can be towed over snow or mud and will float

14
Articulated aircraft cocoon with high pressure inflated ribs. Frankenstein and Sons Ltd.



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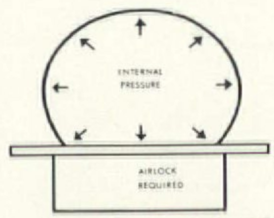

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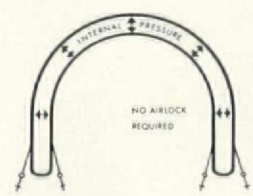

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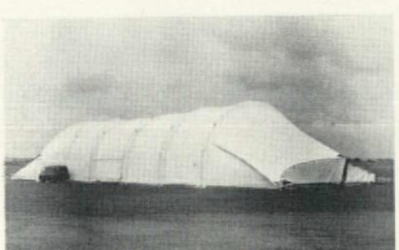

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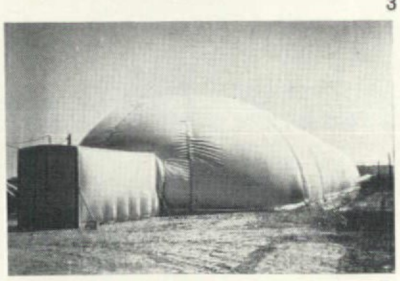

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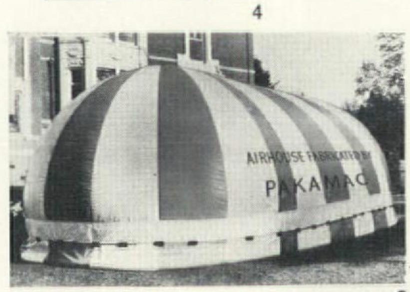

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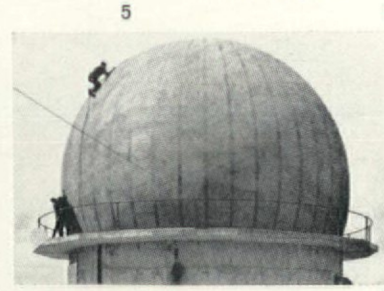

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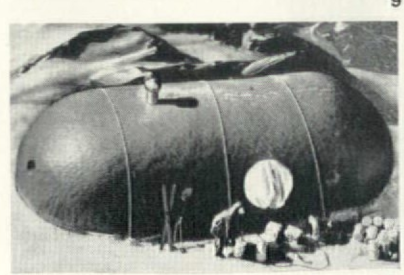

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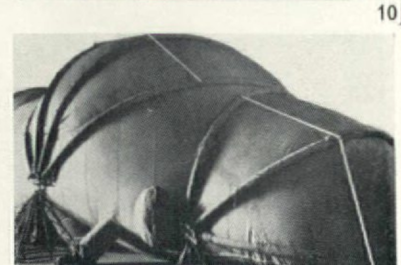


14

Structural plastics

B. Hughes, B.Sc(Eng.) and R. L. Wajda, Dipl.Ing.AMICE

Basically, matter can be divided into two classes, the crystalline and the amorphous. In the crystalline state matter is arranged in a perfectly orderly manner, according to the laws of lattice structure, whilst in the amorphous state matter is in a complete disorder.

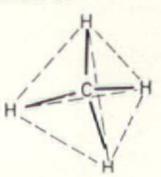
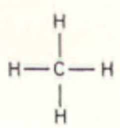
The state in which matter exists determines its properties and thus its usefulness. Metals are examples of matter existing in the crystalline state, while plastics are matter existing normally in the amorphous state. In certain instances some plastics can be made to exist in the crystalline state as a result of special processing, where the random array of molecules are forced into an orderly pattern, e.g. some synthetic plastics fibres. The molecules of an amorphous substance have a relatively large degree of freedom compared to the molecules of a crystalline substance, and the plasticity of amorphous substances is very much dependent on temperature.

Plastics, because of their amorphous nature, are characterized by low elastic moduli, ranging from about $0{\cdot}4 \times 10^5$lb/in^2 for some thermoplastics materials (polyethylene of medium density) to between 3·0 and $4{\cdot}0 \times 10^6$lb/in^2 for some glass cloth reinforced epoxide resins.

Chemical nature of plastics

Plastics are organic materials with very high molecular weights, constructed from simpler repeating units under suitable conditions of heat and catalysis. The 'building-up' of plastics from simpler units arranged in a repeating orderly pattern is called polymerization and plastics are high polymers. Plastics of current practical interest consist of two essential elements, carbon and hydrogen. It is possession by carbon of four valencies, and its ability to satisfy any of these valencies by combination with other carbon groups having an unsatisfied valency, which accounts for the existence of the vast number of carbon compounds which are found in nature, or which can be synthesized.

If the four valencies of a carbon atom are each satisfied with a univalent hydrogen atom, the simplest arrangement of carbon and hydrogen results. This molecule is called methane (CH_4), which at normal temperatures and pressures exists in the gaseous state. In methane the four hydrogen atoms are arranged around the central carbon atom in a tetrahedral fashion **1**.

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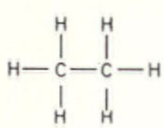
The molecule with the next highest molecular weight is ethane, (C_2H_6), consisting of two carbon atoms and six hydrogen atoms **2**.



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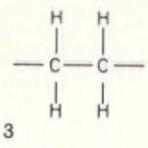
Here the four valencies of each carbon atom are satisfied by three hydrogen atoms and the one unsatisfied valency of the other carbon atom. In fact ethane can be considered as consisting of two methane molecules in which one hydrogen atom has been removed from each molecule and the two carbon atoms joined together. This process can be repeated to give larger molecules consisting of long chains of carbon atoms in which two hydrogen atoms are attached to each atom of carbon. The basic unit is called a monomer **3** and these are built up to form a polymer **4** where *n* is large. If *n* is more than 50, there will be over 200 carbon atoms in the chain and the material is called a high polymer. In this case the molecule is polyethylene, more commonly called polythene.



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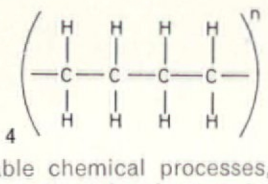

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Furthermore, by suitable chemical processes, any hydrogen atom in such molecules can be replaced by an atom having unit valency, such as chlorine, or by any group of atoms which has an unsatisfied valency.

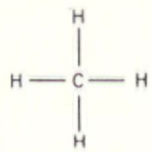
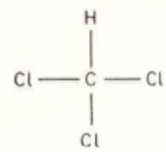

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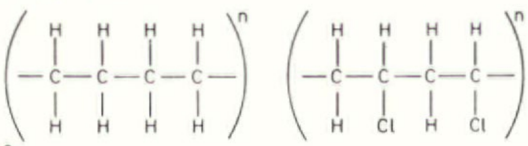
Figure **5** represents the formation of chloroform, ($CHCl_3$), from methane, (CH_4), by replacing three hydrogen atoms of the methane by three atoms of chlorine.



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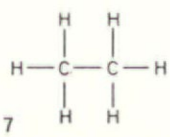
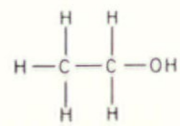
In a similar way, **6**, represents the formation of polyvinyl chloride, PVC, from a high polymer.

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The replacement of an hydrogen atom by a group of atoms is shown in **7**, where a hydrogen atom of ethane is replaced by the hydroxyl, OH group of atoms, thus forming ethyl alcohol, CH_3CH_2OH. In a similar way a very wide range of other polymers can be built up. This 'building-up' of polymers from simpler monomers is called polymerization, this method of replacing hydrogen atoms by another atom is termed addition polymerization.

There is a second type of polymerization called condensation polymerization, in which each time a unit is added to the chain another smaller unit, usually water, is removed. A simple example of condensation polymerization is the formation of an ester by the process known as esterification. This is represented as follows:

$$C_2H_5O\boxed{H + HO}OCCH_3 = C_2H_5OOCCH + H_2O$$

ethyl alcohol + acetic acid = ethyl acetate + water

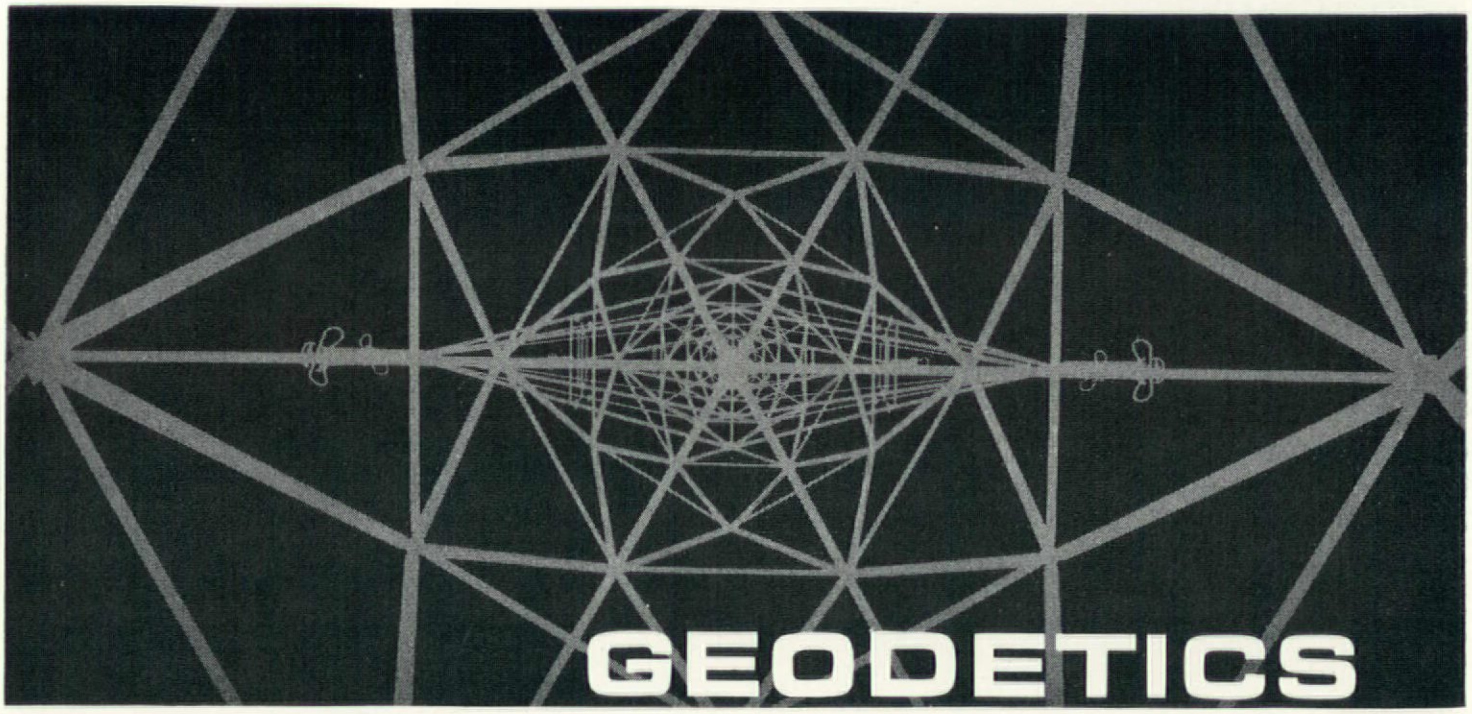
Polyesters are examples of condensation polymerization, and the term 'polyester resin' refers to a variety of resins produced by the condensation of polybasic acids with polyhydric alcohols, or from derivatives of these substances.

Although the number of individual plastics materials produced commercially throughout the world must run into many hundreds, they can all be broadly classified under two headings (1) the thermoplastics; and (2) the thermosetting products.

Thermoplastics are formed when the simple units combine into long chains of molecules forming a two-dimensional linear system. These long polymer chains are separate units and have no chemical link with surrounding molecular chains, but are attracted to each other, and held together by what are called 'secondary valency forces'. Typical examples of thermoplastics materials are polyvinyl chloride (PVC), polystyrene, cellulose acetate, polyethylene, polymethyl methacrylate (Perspex), etc. Thermoplastics materials are those which can be softened and remoulded indefinitely by repeated heating and freezing. Thermoplastics materials exhibit considerable creep under loading, especially at elevated temperatures where the chains of molecules become increasingly mobile. When a load is applied to thermoplastics the chains of molecules 'slip' over each other, and when the secondary valency forces are destroyed, the material will fail.

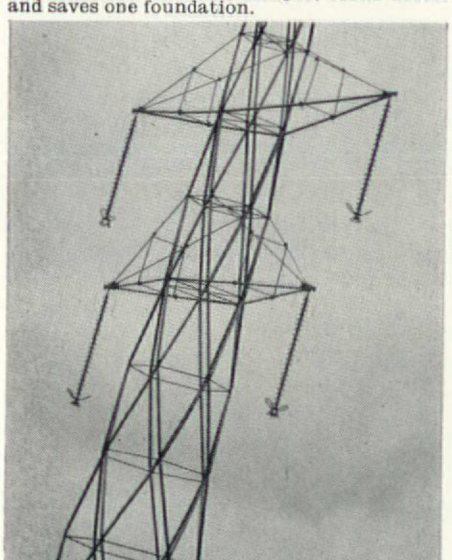
The thermosetting plastics, on the other hand, undergo chemical changes when they are subjected to the action of the required heat and pressure, and are thereby converted into insoluble, infusible masses, which cannot be further remoulded. By virtue of chemical cross-linking between the individual polymer chains, thermosetting plastics form into a three-dimensional matrix. Here the chains of molecules are held together by both secondary valency forces, as in thermoplastics materials, and by 'primary valency forces', provided by the chemical cross-linking of the polymer chains. Thermosetting plastics are characterized by higher elastic moduli than thermoplastics, and have much less tendency to creep under load; they are also usually harder and far less temperature sensitive than thermoplastics. They are usually thick liquids called resins which harden when catalyzed under the application of heat and pressure. They are said to be 'cured' when all the free chemicals are combined. Examples of thermosetting materials include polyester, phenolic, silicone and epoxide resins.

At the present time a knowledge of the chemical composition of a plastics material enables quantitative predications of its properties to be made, but it is likely to be a long time before there is sufficient understanding of all the factors involved to enable a complete quantitative predication to be made. It can be expected, for example, that as the molecular weight of polythene increases, so in general will the tensile strength, its elasticity, and the resistance to impact shocks. It is not possible, however, to forecast the exact values of any of the above or other properties of polythene. Generally, by varying the chemical constitution, the average molecular weight and the molecular weight distribution, by the spatial arrangement of the constituent groups in the molecule, the chemist can make a very large number of products, and *within limits* can produce plastics with certain desired properties 'built-in'. The thermal, mechanical, optical and electrical properties and the chemical and weathering resistance can, for example, be controlled to some extent.



A computer played a vital part in the design of the geodetic tower, and also provided detailed manufacturing data for individual members. This data is fed to machines to cut the tube lengths, and to relatively simple jigs in which the joint parts can be incorporated with the tubes at precisely the correct angles. The control desk of Tubewrights' own digital computer is illustrated below.

Prototype 400kV transmission tower designed and erected as part of Tubewrights' intensive research programme. Strong, lightweight and aesthetically pleasing, this structure nevertheless employs less metal than conventional towers. Ideas on future geodetic designs point the way to a tower with three, not four, legs. This is easier to build, cheaper, looks better and saves one foundation.



News of exciting developments currently taking place at

TUBEWRIGHTS

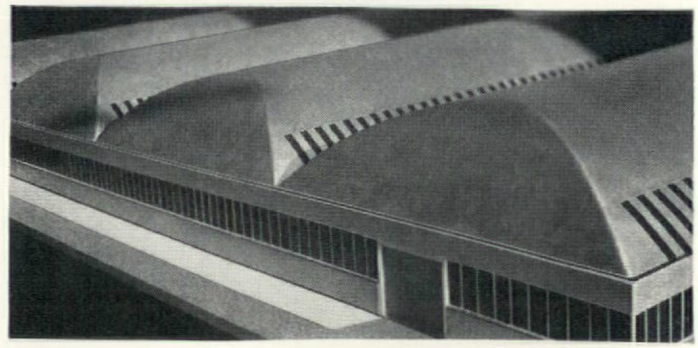
As part of an intensive research programme on the design and erection of geodetic structures, Tubewrights recently erected an experimental 400kV transmission tower at their Kirkby Works, near Liverpool. Advanced geodetic techniques give an immensely strong structure which is light and open in appearance, and which uses less metal than conventional towers.

In order to solve the many complex structural and mathematical problems inherent in geodetics, designers and engineers at Tubewrights use a computer to calculate a structure's dimensions, the loads in all the members, and the best tube size for each member. The computer will provide a cutting list for all tubework, and data on the angular orientation of joints. It will also print out a bill of material and price it.

Not only are Tubewrights well to the fore in the theory, but also in the *practice* of geodetic design. Work is currently in progress to produce the most efficient designs for radio and smoke stack towers, and barrel vault roofs, leading on to domed and shell roofs of theoretically almost any shape.

This advanced study of modern geodetic design, combined with the acknowledged superiority of tubular and R.H.S. sections as structural components, mean that Tubewrights are qualified to undertake projects of unprecedented complexity — opening up new horizons for architects, designers and engineers. For complete details of Tubewrights activities, please write to the address below.

Computer techniques enable Tubewrights to produce highly efficient geodetic designs for radio and smoke stack towers, barrel vault roofs (*illustrated*), leading on to domed and shell roofs of theoretically almost any shape.



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TS 4

Structural properties of plastics materials

Plastics materials all have low specific gravities, about one-fifth that of cast iron. They are all organic materials and therefore combustible, although some of them can be treated to have self-extinguishing characteristics.

All plastics possess high thermal expansion coefficients (about ten times that of steel) thus expension problems are commonly encountered. All plastics materials are strong; they have high strength/weight ratio. Creep properties, however, are not favourable and not comparable with conventional building materials such as steel and concrete. It is therefore important to use plastics in load-bearing applications only where low stress levels are expected. Their modulus of elasticity is low when compared with traditional structural materials and therefore it is not possible to use plastics in structural applications as direct substitutes for the beam and column type of construction. Suitable structural forms must be evolved to overcome this deficiency. Folded-plate structures, for example, derive their strength from the stiffness of the folds, and compensate for the low rigidity of plastics materials. Plastics materials, in combination with rigid plastics foams, can be prefabricated into sandwich construction and in this way high stiffness can also be obtained.

Generally plastics have much to offer to the building industry, where different applications require a specific combination of properties.

Structural types

There are about 40 distinct groups of plastics materials available commercially. Fortunately there are only some six materials which are of importance in structural application. These are: polyvinyl chloride (PVC), polythene, polypropylene, polymethyl methacrylate, polyester/glass fibre, and miscellaneous foamed plastics.

Polyvinyl chloride (PVC). Polyvinyl chloride has been in commercial production for above 30 years. It is a transparent, colourless, rigid polymer which can be transformed into many translucent or opaque shades and colours. It is comparatively cheap and possesses good weathering properties and excellent corrosion resistance. At present there is a large and growing use of PVC in the production of rain water pipes and pipes for domestic water installations.

Polyethylene. This thermoplastics material has been produced in this country for over 20 years. It is noteworthy for its outstanding toughness, low density and impermeability. It is used widely in the form of piping and pipe fittings.

Polypropylene. Polypropylene, a thermoplastics material, behaves very much the same as if it were a rigid form of polythene. It can withstand temperature above the boiling point of water.

Polymethyl methacrylate (Perspex). Again this is a thermoplastics material, which has been in production for over 25 years. It is usually transparent and has been widely used for dome lights and in the cockpits of many aircraft. It is characterized by good outdoor weathering performance and an ability to take many attractive shades and colours.

Polyester-glass fibre laminates possess exceptional strength and resistance to impact and on a weight basis are among the strongest materials known to man.

They consist of glass fibre in a polyester matrix. The function of glass fibre is to reinforce the resin, the basis of reinforced plastics.

Foamed or expanded plastics belong to a group of materials in a cellular form with densities as low as one pound per cubic foot. The most common types of foamed plastics are: foamed polystyrene, PVC, phenolic resins and polyurethanes. These materials are used for insulation purposes, and as cores for various kinds of sandwich constructions.

Reinforced plastics

Reinforced plastics are a group of materials usually having fibrous reinforcement bonded usually by a thermosetting resin system. In general the reinforcement controls the density and mechanical properties, whilst the plastic material controls its chemical, thermal and electrical properties. The resin properties can be further modified by the addition of fillers, plasticizers, pigments and other additives. Reinforced plastics are, of all plastic materials, most suitable for structural applications as load-bearing structural elements.

By far the most popular and useful reinforcement is fibreglass. The addition of glass fibre reinforcements to a plastics material increases its mechanical strength, stiffness, impact resistance, dimensional stability, and gives it a wider useful temperature range. Glass reinforcement can be used in a variety of forms including continuous strands, chopped strands, bi-directional and uni-directional cloths. This gives the ability to select the type of reinforcement to suit the required performance of the application under consideration.

Like steel reinforcement in concrete, the strands of glass reinforcement in plastics can be placed directionally to resist specific loads. It can also be placed in a random pattern to produce uniform strength properties in all directions.

The technological field to reinforced plastics is rapidly developing and it is already the subject of several books and numerous shorter treatments of the field (see page 680)

Types of resins

Although various thermosetting resins, such as the phenolics and epoxies, are used in combination with glass-fibre reinforcement, the polyester group has found the widest use. Certain thermoplastics such as PVC and polystyrene have also been used, but their success has been limited.

Polyesters are the cheapest and most widely used resin and require only low temperatures and pressures for curing. Generally they can be produced, by slight variations in their chemical composition, to have fairly good mechanical properties, chemical resistance and low water absorption. By the employment of certain additives their inflammability can be reduced and their weathering resistance increased. Additives, however, usually reduce their mechanical properties.

The epoxide resins have good mechanical properties, low moisture absorption and very good chemical resistance. Their electrical properties are also good, but the epoxides are expensive and are more difficult to fabricate than the polyester resins.

Silicone resins are used in low-pressure reinforced laminates for applications where heat resistance, usually in combination with excellent electrical properties is required. Their mechanical strength is relatively low, but a high percentage of their initial strength and electrical properties are retained for a long period of time, even when exposed to moisture or temperatures in the range of 500°F. Silicone resins are expensive and quite difficult in handling.

Acrylic Syrup

For applications where good weathering resistance is essential, a polymethyl methacrylate syrup may be used in low pressure reinforced plastics. Their mechanical strengths are moderate but their weather resistance and light transmission characteristics are excellent.

Phenolic resins are mostly employed for high pressure and temperature applications, and have good mechanical and electrical properties. Although they are quite cheap they require high temperatures and pressures for curing and this represents a considerable disadvantage.

Types of reinforcement

Glass-fibre reinforcement

The glass-fibres used for reinforcing plastics are usually of the continuous filament type, that is they are produced from molten glass by a continuous drawing process. The glass-fibres are then fabricated into suitable forms which can be used to reinforce plastics. An important factor in glass-fibre reinforcement is the finish on the glass—this can give considerable improvements in its properties. These finishes are believed to produce a deformable layer at the resin/glass interface and so provide relaxation of shear stresses. The glass-fibres can undergo various surface treatments depending upon their intended use and desirable properties.

The tensile strength of a commercially produced fibre ranges from about 180,000 to 220,000lbf/in^2, with an elastic modulus of approximately 10×10^6lbf/in^2.

Chopped strand mat

The mat consists of glass strands chopped to a suitable length of usually 2 inches. In its manufacture the strands are deposited, in a random pattern, on a conveyor and a binder is applied to hold them loosely together. The manufacture is usually restricted to three weights of mat—1, 1½ and 2oz per square foot, although heavier mats are available.

Because of the random pattern of the fibres, chopped strand mat is usually considered to give isotropic laminates; however, if care is not taken during the depositing of fibre, pattern can be produced and this results in a mat with directional properties. Chopped strand mat is the cheapest of all glass-fibre mat reinforcement, but it has poor mechanical properties.

Rovings

Rovings are rope-like bundles of untwisted glass strands, the number of strands can be varied but the most common is when 60 'end' rovings are used. Rovings are amongst the lowest cost glass-fibre reinforcements. They can be used when local uni-directional reinforcement is required, or woven to give bi-directional fabrics.

Cloths

Cloth reinforcements have maximum mechanical properties for glass-fibre reinforcement and produce the highest density laminates. Many types of glass-fibre cloth reinforcements are available, varying in weight, thickness, type of weave, type of yarn employed and the glass filament diameter. The types of weaves used include plain (or square) weave, twill weave, satin weave and unidirectional weave.

All cloth reinforcements possess directional

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properties corresponding to the warp and weft yarns, which are the two principal directions. Warp yarns are those which run along the length of the cloth while the weft yarns are those which lie at right angles in the cloth. In preparing a multi-layer laminate, due consideration must be given to the orientation of the various layers of cloth, so that the necessary directional strengths can be developed.

In laminates where the main stress is tensile, a large number of layers of a very thin cloth give the best results, and when shear is the predominate stress, a few layers of thicker cloth produce the best results. Low crimp cloths are best suited where the stresses are compressive or flexural.

Other types of reinforcement

There are, in addition to glass-fibre, three other main types of reinforcement used in plastics for specific applications:

Asbestos, used for high temperature applications;

Paper, used in the wide field of high pressure laminates;

Natural fabrics, most natural fibre-based laminates are made from cotton cloth usually used in the manufacture of gears and bearings where resistance to shock loading is important.

General design considerations for reinforced plastics

Reinforced plastics are a combination of two widely dissimilar materials and only in certain instances, ie chopped strand mat laminates, can the combination be considered as being isotropic. When designing with cloth, rovings etc., the formula for isotropic homogenous materials are not valid and the directional properties of these materials must be considered.

Two important assumptions are made when designing glass-fibre reinforced plastics. The first and most fundamental of these is that at the interface between resin and fibres a continuity of strain exists. This assumption implies that a good bond exists between the fibres and the resin system. When the composite material is strained, if the stress-strain relationship of the fibres and resin are known, the stress developed in each material can be computed and their combined actions determined.

The second major assumption is that the material is elastic, in that strains are directly proportioned to the applied stress, ie the material obeys Hooke's law. This assumption also implies that any deformation disappears when the material is unloaded. The stress-strain curve of a glass-fibre reinforced plastics is in fact the combination of two stress-strain curves, that of the glass-reinforcement and that of the resin. While glass has a high proportional limiting stress, the stress-strain curves of most resins have no well defined linear section, but rather there is deviation from linearity from the origin. The resin can then be expected to undergo plastic flow leading to creep or relaxation of stress, especially at high stresses as the amount of plastic flow or permanent deformation depends upon the stress level.

The second assumption is therefore probably a close approximation for direct stress below the proportional limit where the glass-fibres carry practically all of the stress. However the assumption is probably less valid in shear where the resin system carries a large portion of the stress.

There are several methods of definining the elastic modulus of plastics, the one usually employed for reinforced plastics is that calculated from the slope of the straight line form the origin of the stress-strain curve, ie the tangent modulus. With thermoplastics, although the initial tangent modulus is usually quoted in most published figures, the concept of a 'modulus accuracy limit' is perhaps more valid.

The stress-strain curves for thermoplastics show no linear section and the sectant modulus, ie the slope of a straight line drawn from the origin to a point on the curve, decrease with higher strains. The graph of the ratio of secant modulus to initial tangent modulus against strain emphasizes that the application of the initial tangent modulus becomes less accurate with increasing strain. As an arbitrary choice, Baer *et al*. chose an accuracy of 15 per cent as an allowable error in most design calculations, and thus defined the strain at the 'modulus accuracy limit' as that corresponding to a value of the ratio of secant modulus to initial tangent modulus equal to 0·85. On any specific design problem, if the strain at the 'modulus accuracy limit' was not exceeded, design calculations were assumed to be sufficiently accurate.

When considering the elastic modulus of plastics, it should be pointed out that the moduli in tension, compression and flexure are not necessarily the same and ideally the modulus corresponding to the particular type of stress under consideration should be employed.

Most structural materials, such as steel and aluminium, yield and have yielded strengths considerably lower than their ultimate strengths. In the case of glass-fibre reinforced plastics the yield and ultimate strengths are almost identical and are usually considered to be the same. Unlike metals, glass-fibre reinforced plastics cannot yield without rupture to relieve stress. The fibres in glass-fibre reinforced plastics are not all straight and the initial stress in all the fibres is not the same. When a load is applied certain fibres fail first and as they fail their loads are 'spread' to the surrounding fibres which as yet are unbroken. Thus failure is caused by the successive failures of each fibre rather than by the simultaneous failure of all.

The structural design of all plastics requires a knowledge of strength and stiffness as functions of time, temperature and environment. Information on the effect of time and temperature on the properties of plastics, however, is very incomplete. The properties of glass-fibre reinforced thermosetting plastics are far less affected by time and temperature than are those of thermoplastics materials. The phenomena of creep and relaxation in thermoplastics are of prime concern in design as creep will take place even at low stress levels and low temperatures.

For Perspex, a thermoplastic acrylic material, the effect of temperature on the elastic modulus can be represented approximately:

Elastic Modulus in Flexure $= (5{\cdot}26 - 0{\cdot}042T) \times 10^5 \text{lbf/in}^2$

where $T =$ temperature in °C.

Thus at a temperature of approximately 125°C the apparent flexural modulus is reduced to zero. With steel, creep phenomena is usually only encountered at elevated temperatures and is therefore of less importance.

Besides the effect of temperature, plastics materials suffer a reduction in their ultimate strengths and elastic moduli with time, even under static load conditions.

The mechanical properties of plastics are also affected by environmental conditions, and it is recommended that the values of mechanical properties used in design should be those obtained from tests performed under the same, or as near to the same environmental conditions as the final structure will be subjected.

The initial properties of glass-fibre reinforced plastics depend upon a number of factors, of which the most important are:

Type of resin
Type of reinforcement
Proportion of resin and reinforcement
Fabricating techniques.

The first two factors are more or less self-explanatory as different types of resin and reinforcement have different properties. Glass-fibre reinforcement has far superior mechanical properties than the resin and, obviously, all mechanical properties will increase with increasing glass content. However, there is a practical limit to the glass content of any glass-fibre reinforced plastics, depending upon the type of reinforcement used. The usual glass contents are approximately:

Chopped strand mat laminates	40% by weight
Cloth laminates	60% by weight

The corresponding resin contents are usually sufficient to ensure good resin impregnation of the reinforcement, and to enable moulding to be performed without much difficulty. The glass contents stated above refer to hand lay-up contact moulding and not pressure moulding where the resin content can be reduced, resulting in stronger laminates.

The fabricating technique can have great bearing on the properties of a glass-fibre reinforced plastics, however the effect of fabricating variables such as workmanship are difficult to estimate.

All plastics materials, being organic in nature, are inflammable to some extent. The inflammability, however, depends on a great number of conditions such as the source of ignition, the temperature of the material and its previous chemical or physical history. Fire-retardent agents can be added to the resin system which greatly reduces their inflammability. The fire retardent resins used in glass-fibre reinforced plastics are usually made either by the addition of an additive such as antimony trioxide, or by using an additive containing chlorine, such as chlorendic acid. However, weathering tests have shown that the deterioration of resins incorporating fire-retardents is severe.

Measuring the mechanical properties of reinforced plastics materials presents many difficulties. Firstly, the materials are not homogeneous and differences in the conditions of fabrication vary the degree of homogeneity. Secondly, the measured values will depend on a number of factors including the temperature, shape of the specimen and the rate of straining. Higher rates of straining yield higher mechanical properties but it is difficult, if not impossible, in practice to define the rate of strain at which a specimen should be tested. In some cases the above factors can lead to considerable variations in the values of mechanical properties of reinforced plastics. It has been proposed that in such situations the use of statistical techniques as an aid to interpretation of test data is a necessity.

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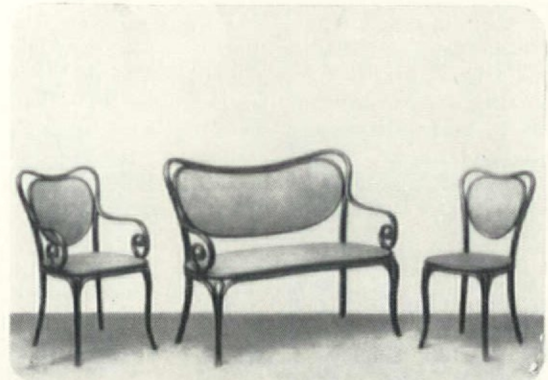

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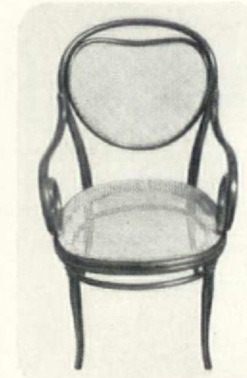

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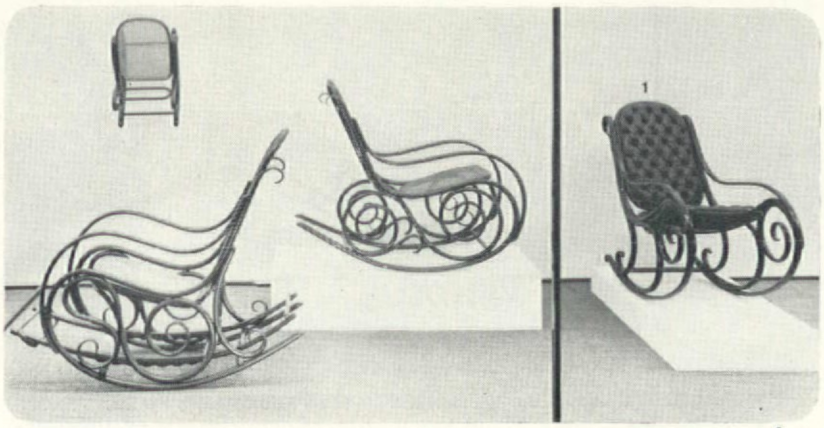

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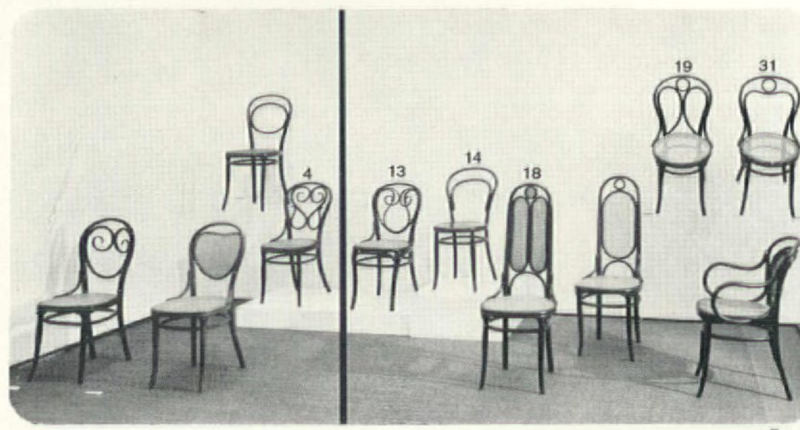

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Thonet

Last September an exhibition of the work of Michael Thonet was held at the Austrian Building Centre (in the Liechtenstein Palace). It was designed by architects Karl & Eva Mang. We publish extracts from their catalogue.

1
Handmade armchair by Michael Thonet, Boppard, 1836–1840
2 & 3
Chairs by Carl Leistler (2) and Michael Thonet for the Liechtenstein Palace, 1842–1847
4
Michael Thonet, chairs exhibited at the Great Exhibition, 1851
5
Thonet chair **No. 3**
6 & 7
The Vienna exhibits numbered as in the catalogue
8
Detail of a Thonet catalogue
9
Chair, **No. 9**, made famous by Le Corbusier
10
Seat frame template
11
The Vienna exhibition showing early Thonet experimental chairs—a bent plywood model and a fantastic chair made from one continuous piece
12 & 13
Chairs **Nos. 56** and **221**

Photograghs 6, 7 & 11 P. Grünzweig

CHRONOLOGY

1796 Michael Thonet born in Boppard/Rhine-Prussia

1819 Independent business as building and furniture carpenter/joiner

1830 Experiments in making furniture out of parts glued to each other

1841 Patents in France, England and Belgium (never used) Exhibition in Koblenz: Prince Metternich notices Thonet's work. Thonet introduces his designs to the Austrian Court at Johannisburg Castle

1842 Awarded patent from the Royal Court in Vienna Financial difficulties in the valuation of the patents: furniture, intended for the Court in Vienna, confiscated in Frankfurt/Main at the insistence of the creditors. Loss of living and fortune
Emigration of the Thonet family to Vienna

1843–46 Michael Thonet works under Carl Leistler on the interiors of the Liechtenstein Palace (Architect: P. H. Desvignes)

1849 Independent activity in Vienna
Chair **No. 4** (made from 4 or 5 thicknesses of mahogany)

1851 Thonet furniture at the London World Exhibition 1851 ('Luxury furniture' class)

1853 Firm was handed over to the five sons Franz, Michael, August, Josef and Jakob. Michael Thonet retains control

1855 Exhibition in Paris. First export order to South America

1856 Austrian citizenship for Michael Thonet and his sons First Thonet furniture factory in Koritschan, Moravia, designed by Michael Thonet

about 1857 Principles of organization: division of labour, introduction of mechanical working, often with homemade machines

about 1859 Furniture parts made from solid pieces only

1859 Chair **No. 14** (total production approx. 50 million)

about 1860 Manufacture of cartwheels from bentwood

1860 First rocking-chair **No. 1**

1861 Factory in Bystritz-am-Hostein

1862 World Exhibition in London: ('Cheap consumer products' class)

1865 Factory in Grosz-Ugrocz

from 1867 Deliveries of beech from Galicia for the Thonet factories

1867 Factory and sawmill in Hallenkau (Wsetin Province)

1867 Chair **No. 18**

1869 Expiry of the patent—first competitive companies

1871 Death of Michael Thonet

1880 Factory in Nowo-Radomsk (Russian-Poland)

1885 Chair **No. 56**

1888 Theatrical folding-chair for the German Volkstheater, Vienna

1890 Factory in Frankenberg, Hesse

1870–90 Leasing of many sawmills

about 1871 Sales establishments in existence in: Prague, Graz, Munich, Frankfurt/Main, Brussels, Marseilles, Milan, Rome, Naples, Barcelona, Madrid, Bucharest, Petersburg, Moscow, Odessa, New York, Chicago

1898 Chair **No. 221**

1923 Merger 'Thonet-Mundus'

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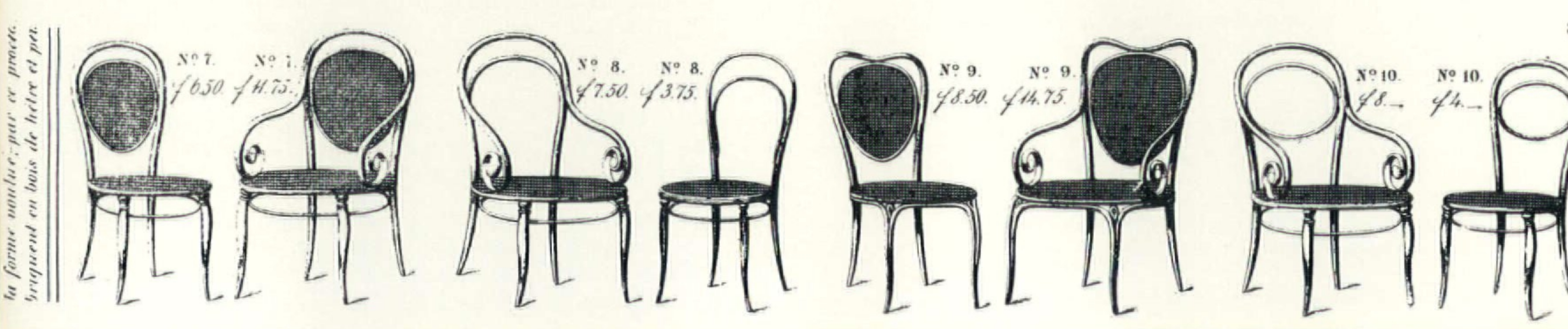

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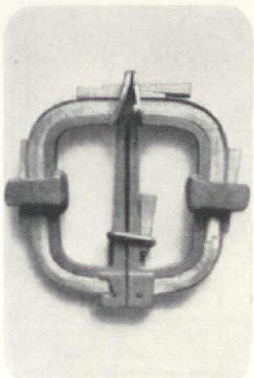

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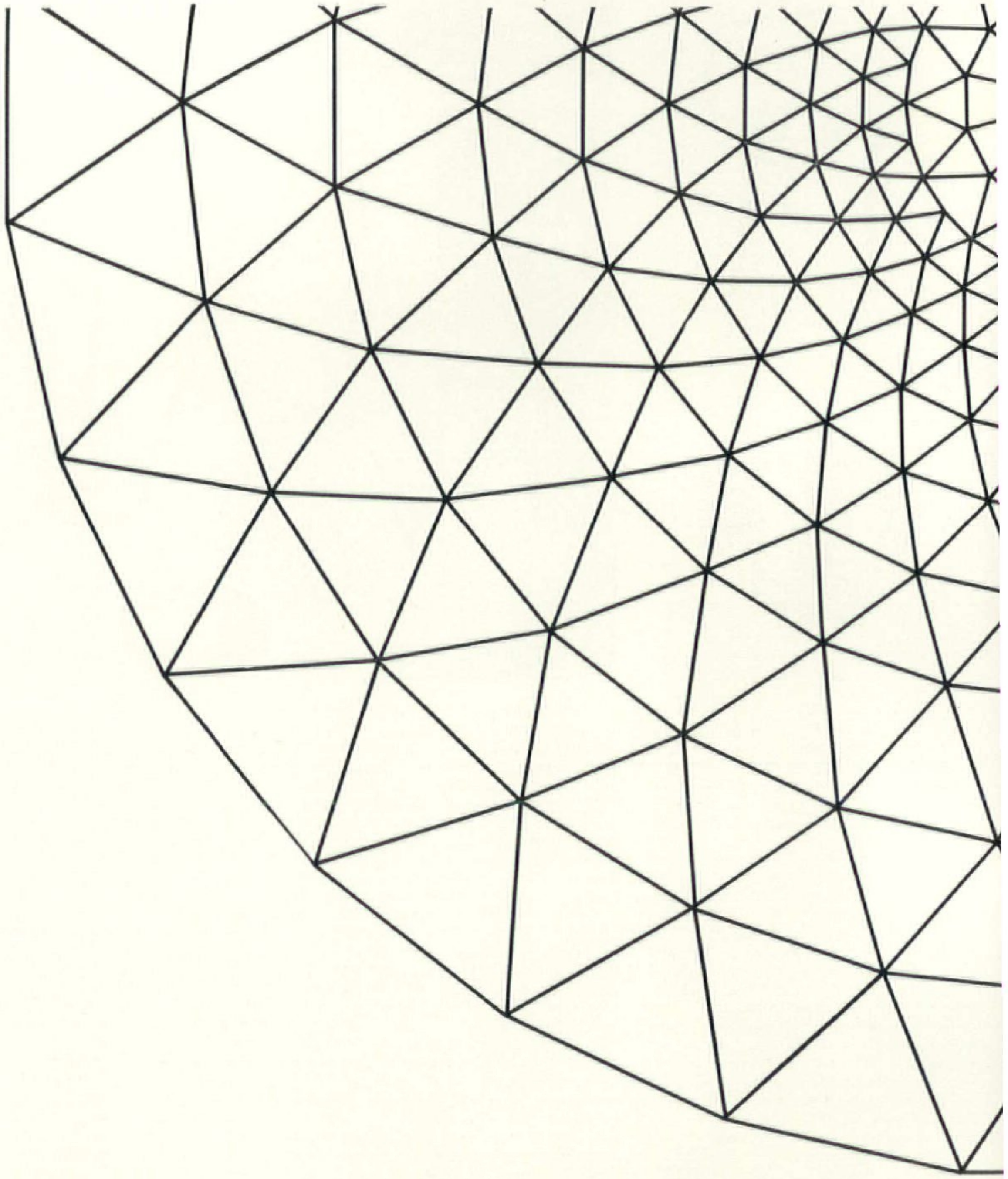
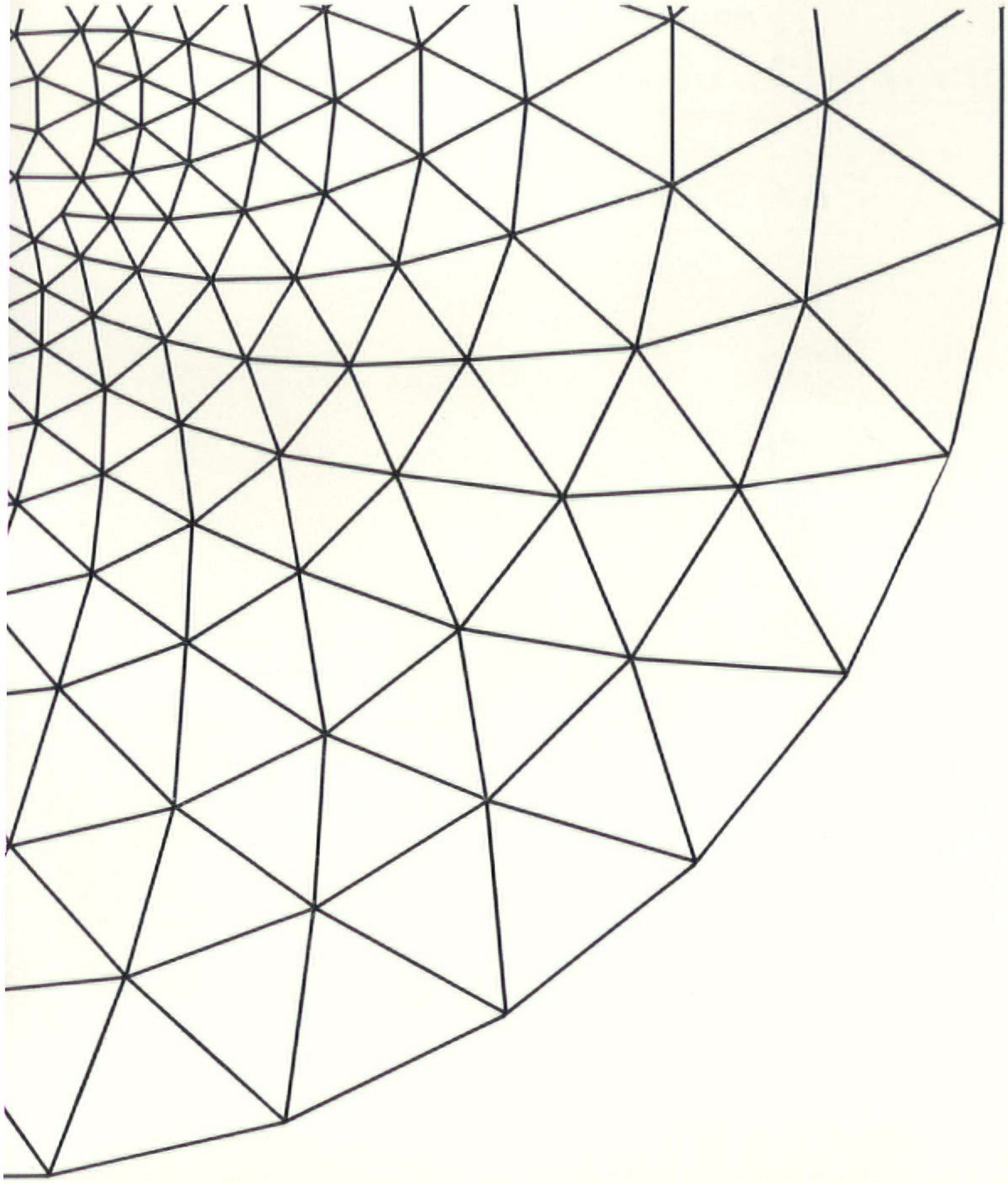
When Michael Thonet died in 1871, he left his sons an undertaking that was in the forefront of Austrian industry. In 1900 the company employed over 6000 workers; 20 steam machines totalling 1100 horse-power produced 4000 pieces of furniture daily.
The patent granted on 10th July 1856 guaranteed sole production rights until 1869 for 'the finishing of chairs and table legs out of bentwood, the bending of which is achieved by the introduction of steam or boiling liquids'. From this time competitors appeared, copying most of Thonet's furniture designs. Around 1900, 26 companies in 35 factories with about 25,000 workers daily produced 15,000 different pieces of furniture, 12,000 of which were chairs. About one-third of the total Austro-Hungarian production of bentwood furniture was sold at home, two-thirds were exported. In 1899 the annual production amounted to 18 million crowns and total exports were 14,322,800 kilos. These figures increased until the outbreak of the First World War. In 1910 there were 52 companies with more than 35,000 workers in 60 factories using the Thonet patents.
Dr. Wilhelm Mrazek (Keeper of Applied Art at the Austrian Museum)

Michael Thonet had a craft background. The furniture which he made around 1830 in his small Rhineland joinery workshop was popular everywhere and much in demand. The transition to industrialization only came when the idea of bending wood mechanically for quantity manufacture of furniture became a practical proposition. In the work at the Liechtenstein Palace in Vienna in the years 1843–46, chair types evolved whose shape was developed entirely from the technical solution of the design problem—even though entirely hand-made. The then famous firm of Carl Leistler, under whose name Thonet worked on the Liechtenstein Palace, made similar chairs.
The chairs made for the Great Exhibition contain the basis of the shape of the later industrial chair, but especially in individual parts of the chair (chair backs). The triangular connection between front legs and seat framing demonstrates an interesting craft solution to a problem, which was still fully in use in some chair types of the industrial range (**No. 13**) until about 1875. From this luxury furniture in rosewood there gradually evolved various types whose sale was promoted by Thonet for industrial furnishing.
The first factory was erected near red beech forests, a timber which became of decisive importance in the continued production of the bentwood chair. Production boomed just as the last technical difficulties in bending large pieces were solved. In 1860 chair **No. 14** was developed. The 'consumer chair' was born.
The problems of mass-production were solved in the simplest manner. The chairs could be dispatched in parts, assembly consisting merely of screwing the parts together. The chairs were light, strong and usable anywhere and by tightening the screws could be repaired at any time. They were just what Morris and Van de Velde theoretically wanted on the basis of their social attitudes—a piece of furniture which anyone could afford.
Tradition has it that it was August Thonet who, in a corner of the factory with a few colleagues, developed design and construction—a design which, in the case of the best-selling types, achieved a simplicity (we think of armchair **No. 3**, writing chair **No. 9** or rocking-chair **No. 1**) which they continued to produce until our time, usable and aesthetically completely satisfactory. From the few catalogues available it appears that a simplification of production soon led to the elimination of those designs in which individual parts were too like handicraft, chairs **Nos. 9** and **13**. With the introduction of chair **No. 56** (1885) an even simpler use of material was achieved. The length of the necessary knot-free raw material for the back was reduced by one half. Chair **No. 221** combines the comfortable chair back with shapes that could have been borrowed from a second Roccoco period. Here, however, a structurally correct, but possibly somewhat uncomfortable shape was used.
The Thonet catalogues of that period also show furniture whose shapes are often in direct contrast to the, one might say, classic lines of type **No. 14**. Adolf Loos and Le Corbusier used Thonet furniture. Otto Wagner's chairs for the Post Office Savings Bank offices were 'bent' in the Thonet factory, and Joseph Hoffmann and his successors at the Vienna School continuously investigated the potentialities of bentwood.
The Thonet organization remained true to its pioneering spirit. In the Bauhaus period the tubular steel furniture designed by Marcel Breuer, Mart Stam, Mies van der Rohe and Le Corbusier was manufactured at the Thonet factories. Giedion accepts, rightly, that development of tubular steel furniture could quite feasibly have been influenced by 'bentwood'.
The decisive achievement, however, remains the 'consumer chair'. Structural honesty and correct use of material permitted the existence already in 1860 of an anonymous product which fulfilled the requirements of the new-found mass market. *Karl Mang*

Michael Thonet's first experiments were made with the top and central-rear loops of chairs, which connected the sides and formed the back. The process was as follows: instead of cutting the top loop from solid wood, as used to be the case, then working it into the correct shape and then covering it with a finishing veneer, Thonet made it out of thick layers of veneer glued together in a wooden template and press, the template being made to the desired final bent shape. These, pressed into loops, require less timber, were lighter and much more durable. The outside could be covered with a good veneer whilst the inner laminations were made from ordinary wood. The middle loop was similarly glued in wooden templates and pressed. With the more elegant types of chair the thin finishing veneers were specially glued and pressed in hollow, circular metal templates, instead of these being made from the solid by a carver.
After the start had been made with seat backs, Michael Thonet set out to produce the sides of the chair also of strips of veneeer. These were made in such a way that the sides, back and front legs consisted of a continuous piece.
The top and middle-rear loops of the early bentwood chair were thus of veneers glued and pressed in wooden templates, a process in which the veneers were actually soaked in glue beforehand and pressed in heated wooden templates. The sides of the chair, on the other hand, were still made from thick wooden rods which were first boiled in a glue bath in order to make the wood more pliable. *Herman Heller*

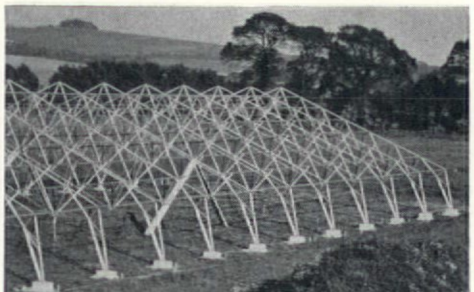
The difficulty of removing moisture from furniture timber, also the desire to simplify the process of manufacture, led to the bending of large pieces of wood. Thonet accomplished this by immersing the thick struts in boiling water and putting them into bent templates which, together with the bent struts, were put into a drying room for several days until the moisture was sufficiently reduced so that the bent piece kept its shape. Since however the wood took longer to dry out fully, the bent parts were slid into presses which were designed to enable the warm air to come into contact with the maximum surface area of the wood in order to expedite the drying time. Only now, after the individual parts were thoroughly dry, were they painted with glue in their warm state and pressed into the final shape. Thus in this case the glue had only to take comparatively little strain.
The most significant phase in the history of this industry then began. Thonet used the following system: onto the straight, unbent strut, onto the part which after bending would constitute the convex side, an iron strip was laid and fixed at several points and at either end with screw-clamps, rigidly and firmly connected to the wooden rod. So, when the latter was bent the wood being bent with the metal strip could not bend more than the strip itself, and could only increase a minute amount in length. In order that it could be bent at all, the entire wood section was in compression, and this increased the further it was from the metal strip, i.e. the nearer it was to the concave surface. No longer was part of the wood in tension and part in compression: the metal strip in its secure connection forced the entire section to be in compression.
Wilhelm Franz Exner ('The Bending of Wood', Leipzig 1922)





aco Triodetic Dome on the City of London Pavilion s only 1½ tons. It is easily transported and can be d in about 10 hours.

A Triodetic factory roof structure, with an area of 15,000 sq. ft. and a weight of 6 tons, was fabricated at floor level and lifted into position, in one piece, in two hours.



The Triodetic system used for two wide-span greenhouses built by Cambridge Glasshouse Company Ltd. for A. G. Sparkes Ltd., Angmering, Sussex.

HE BRITISH ALUMINIUM COMPANY LTD

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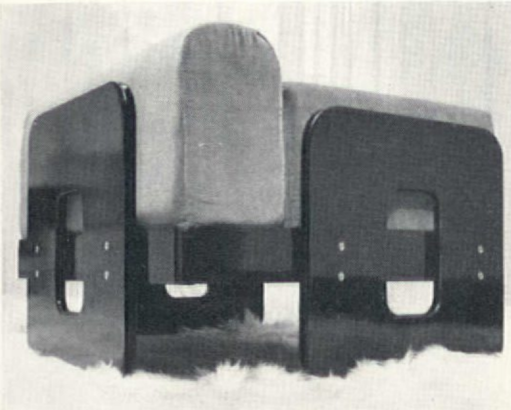
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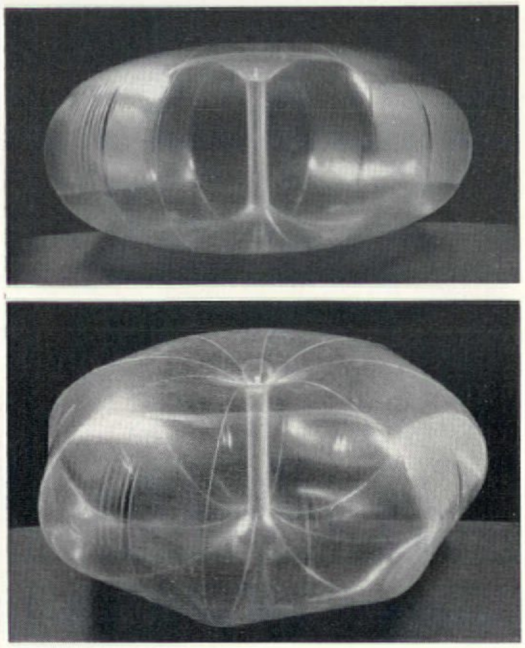
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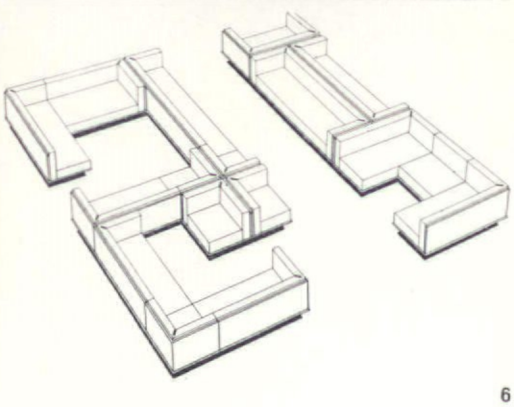
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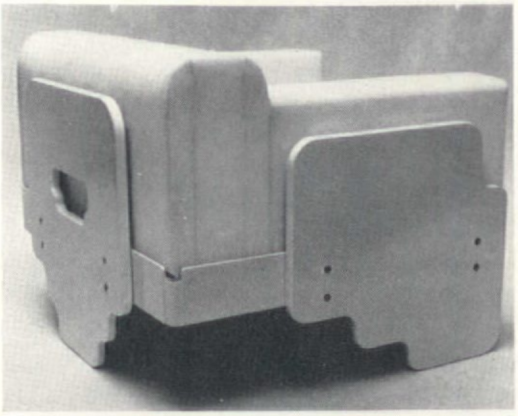
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Design notes

Sitting

On air

Several years ago Denmark's Verner Panton tantalized us with a sight of his (unavailable) colourful translucent air-filled plastic-seating cubes. *Mobilia* published exquisite coloured photos of people apparently sitting on air.
But that seemed to be that. Now the British architect and plastics expert, Arthur Quarmby, experimenting again, has produced a clear PVC pouff **3** with a central, bright orange, perforated tension tube containing the inflation valve in the base.
The first prototype, made by Pakamac and shown at the recent *Sunday Times*/Woodlands exhibition, was 3ft 4in in diameter and 1ft 6in high. But as this required $8ft^3$ of air—rather too much for speedy inflation—any future version would have to be reduced to 2ft 4in × 1ft 0in high, to contain $3ft^3$ of air.

Knock down

Six pairs of brass bolts are all that attach the sides and back to the 2ft 6in box-seat frame of Michael Clendenning's gay easy chairs **1, 2** currently on sale at Liberty's, London. The wood used is ply, spray painted. The seat is a box frame with the new Pirelli 'platform', attached at four points near the top, carrying the seat cushion.
The plastic foam cushions have zipped-on tweed covers—white, black, purple, red or yellow.
Max Clendenning has developed a new series of knock-down furniture, being made by Race, which will be featured shortly in these pages.

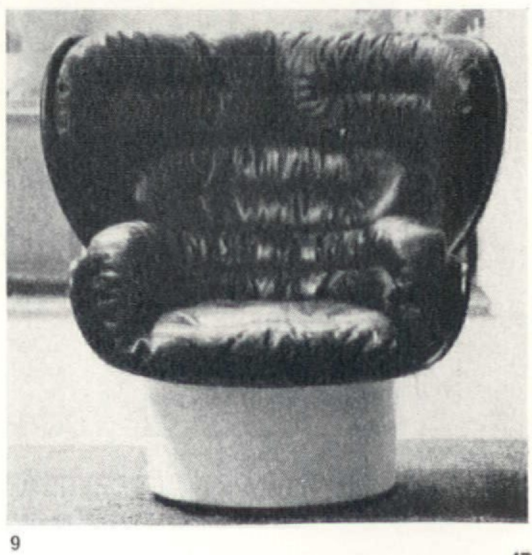
Low cost

Concept Interiors have done it again. They have shown that a good-looking comfortable easy chair **4** does not have to cost a fortune. David Kester-Dodgeson was the designer of their latest study-bedroom chair which, with beech frame and interchangeable seat and back cushions resting on Pirelli webs, costs between £7 10*s* and £10 10*s* depending on the material used for the zipped-on cushion covers.
7 Harley Street, London W.1.

Only in Italy

Martin Grierson designed Arflex's 'Oxford' chair **5** (not yet available in Britain) consisting of two pre-formed ply shells, seat and back, veneered in rosewood and upholstered in leather or PVC over moulded latex padding.

48▷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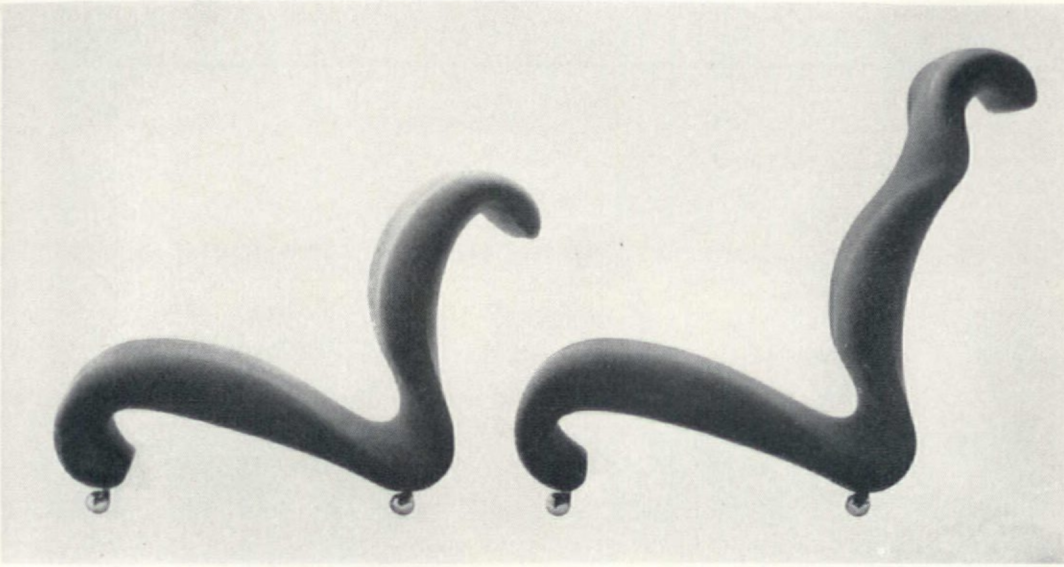

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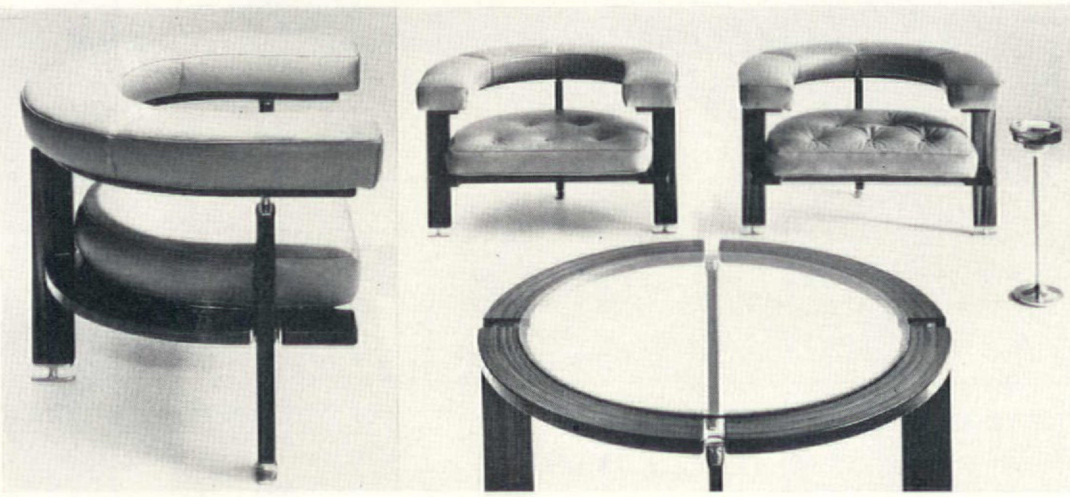

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The upholstery is attached to a secondary shell which is afterwards screwed to the structural shells.
Via Tito Livio 3, Milan.

Mobile MIM's 'Vignola' chair series **6, 7** designed by the architect Luigi Pelligrin, is 82cm³. There are 2- and 3-seaters as well as a corner version with only one 'arm', which build up interesting groupings for waiting-rooms, museums, etc.
The chair's upholstered wooden framework and its reinforced polyester base support rubber strapping for the seat. The cushions are of latex foam with feathers on the user side and zipped-on covers of leather or fabric.
Piazza Augusto Imperatore 32, *Rome.*

Joe Colombo's 'Elda' armchair **8, 9** for Comfort, Milan is more in keeping with the times, with its one-piece luxuriously upholstered plastic frame.
Domus 432, November 1965

Verner Panton in Germany

Panton's latest creations, **10** featured in *Moebel Interior Design*, are being made by Storz and Palmer of Steinheim/Murr. The seats 'consist of shells on very softly adjusted strapping with a foamed plastic combination upholstery' (devised in cooperation with Metzeler AG of Memmingen), and they glide around on ball castors.
MD, 11/65

Only in Finland

Esko Pajamies was asked in 1964 to design high standard, strong and monumental furniture for public spaces.
His first chair and table series **11** uses polished cast bronze parts to link wooden members. Aluminium could be substituted for bronze. The wood chosen was laminated jacaranda, the chair cushions are upholstered in leather, and the chair is knockdown. The table top is glass.
The second series **12** is based on polished cast bronze (or aluminium) leg. The chair's rubber strapped seat is carried by the leather-covered beech frame. The four leather-covered loose cushions are held in place by the leather-covered moulded beech 'balustrade'. The top of a matching table is marble.
Photos Pietinen

Only in Brazil

Sergio Rodrigues, technical director of Rio's 10-year-old furniture firm OCA, and designer of the famous prize-winning floppy-feather-cushioned chair, **15** has more recently produced auditorium seating **13, 14** in jacaranda with chromed metal legs and leather or plastic covered, foam-filled upholstery

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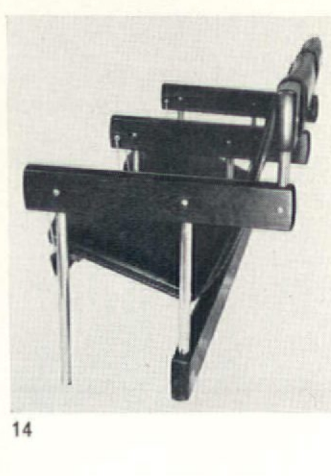

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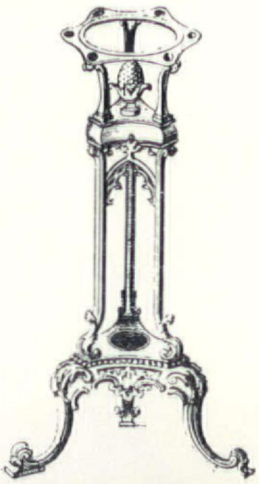
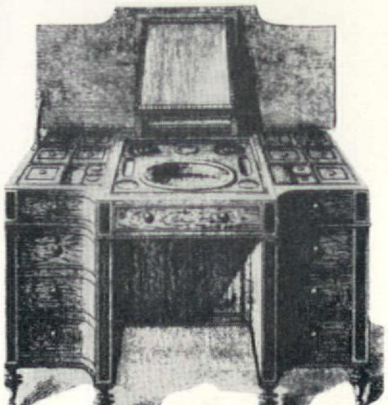
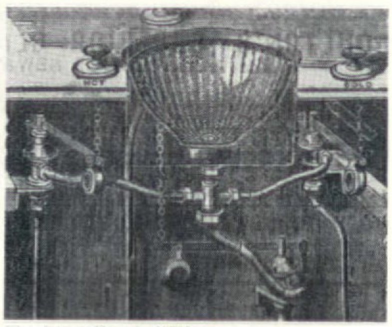
Product analysis 2



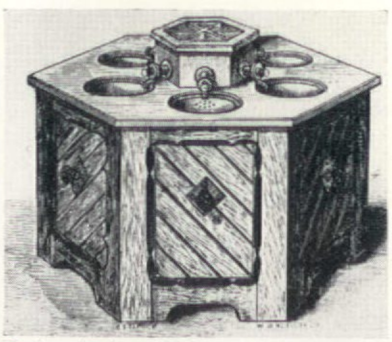
Chippendale basin stand, 1754



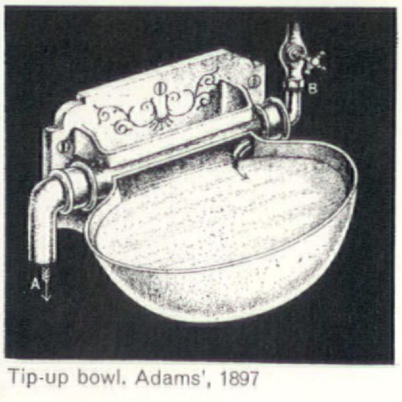
Sheraton dressing chest, 1803



Flushing Bowl, 1871



Factory basins, 1879



Tip-up bowl. Adams', 1897

Basins and bidets

Alexander Pike

Systematic industrial design procedures have long been taught in our colleges of art and technology, and whilst their effect is noticeable on a number of marketed products, our shops, showrooms and warehouses still contain immense quantities of appliances and items of equipment that reveal no evidence of the influence of these procedures. Perhaps insufficient time has passed for the talented output of these schools to supplant the backwoodsmen, or possibly the demand for designers of high calibre exceeds the supply. It is more probable that in too many cases the final responsibility for acceptance or rejection of designs rests with the Board of a company or a nominated director at that all-important decision making level to which the ascent of a designer is a rare occurrence. At this restricted level of assessment logical analysis and systematic methods of design make small headway over subjective opinions based on precedent. The products which suffer most are those with a long history of gradual development behind them which, instead of serving as a reservoir for analysis of past mistakes merely acts as a norm, providing a yardstick against which all future designs are judged and to which all successive waves of development eventually revert. Items which suffer least (but still profoundly) are those which serve a new function and admit fewer preconceptions.

The Lavatory Basin and Bidet are interesting subjects for comparative analysis each being representative of the above situations, the one has a record of well over thirty centuries of development, the other, although introduced in France at the beginning of the eighteenth century and judged by the same time scale as a newcomer, almost unknown and little used in this country.

Initial development

In the history of the lavatory basin time is very much out of joint and reversions are manifold. Minoan Crete was more advanced than Renaissance Italy, and in England both the Roman legionary and the medieval monk had better facilities than the young Queen Victoria. Thus development has been sporadic and interrupted, consisting of several overlaid cyclic patterns; the study of which is purely academic. We could usefully take as our starting point the mid-eighteenth century, when washing habits made more concessions to contemporary taste than to practical performance, and the typical tripod basin stand was considered adequate. This gave way to the shaving or dressing table which aimed at concealing the function by a display of the cabinet maker's art, and was used until some time during the 1830's, when the pretence was dropped and the flat-topped wash stand emerged as a standard item which in some areas was used for more than a century. With the introduction of piped water supply to the upper floors of houses the basin became a fixture beneath a marble top, at first merely discharging into a bucket beneath the outlet but later connected to the drainage system. After 1870 the lavatory basin became the subject of serious consideration and manufacturers offered ingenious mechanisms which, if not entirely practical, displayed a refreshing inventiveness which is sadly lacking today. The Tip-up Bowl with concealed waste, the Flushing Bowl, and the Face Spray (with a fine jet rising from the base of the bowl) all emerged after this date, but did not gain acceptance. The introduction of more sophisticated plumbing provided hot water for the basin as well as cold, and so enabled the more privileged section of late Victorian society to experience the same abluent facilities—if not the same standard of house heating—enjoyed 19 centuries earlier by the citizens of Pompeii. At the turn of the century higher rates of production were achieved and prices considerably reduced by the use of cast iron for the basin stand. This rapidly replaced the encasing wooden cabinet formerly used and led to the adoption of cantilever brackets which eventually enabled the stand to be eliminated. The isolation of the lavatory basin left it in the form in which it is now known, and appears to have been considered not as a turning point, but as a peak of achievement.

In this country the bidet has remained so unpopular since its inception that it has been little developed. First mentioned in France in 1710, it was probably in use here fifty years later, but considered as a French novelty and—as catalogues of the period indicate—discreetly hidden away in dressing stands or bidet tables. Illustrations of one form or another occur after the Great Exhibition of 1851, but they have always been considered as something of an eccentricity and it is only in recent years, probably due to more widespread foreign travel, that they have been used at all in this country. It is hardly surprising that the models available today bear a strong resemblance, to those found in illustrations of bathrooms at the time of the Boer War.

Materials, standards and regulations

British Standard 1188 for Ceramic Lavatory Basins permits the use of earthenware, heavy earthenware, fireclay, stoneware and vitreous china. British Standard 1329 for Metal Lavatory Basin covers products manufactured from enamelled cast iron or pressed steel, and stainless steel. Both standards are restricted to the traditional dimensions, 25in × 18in and 22in × 16in, and therefore, even if suitable dimensional accuracy could be maintained in the ceramic materials, the adoption of either standard guarantees that the fitting cannot be co-ordinated with tiling sizes. Most lavatory basins and bidets are produced in either fireclay or vitreous china,* and whilst there is no British Standard Specification relating to the bidet, its installation is covered by Codes of Practice CP 305, Sanitary Appliances and CP 310, Water Supply.

Few people in this country have ever used a bidet, except perhaps when travelling on the continent, and then most probably as a footbath. It is, therefore, not surprising that until fairly recently there was no clear official indication as to whether the bidet should be treated as a soil or waste fitting, and local water authorities still hold widely differing views on the method of supply of water to the fitting.

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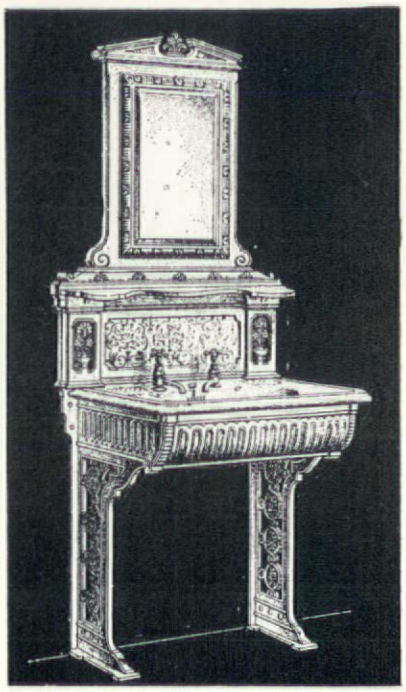
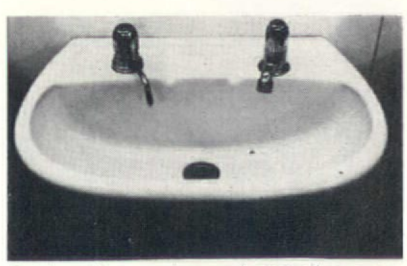


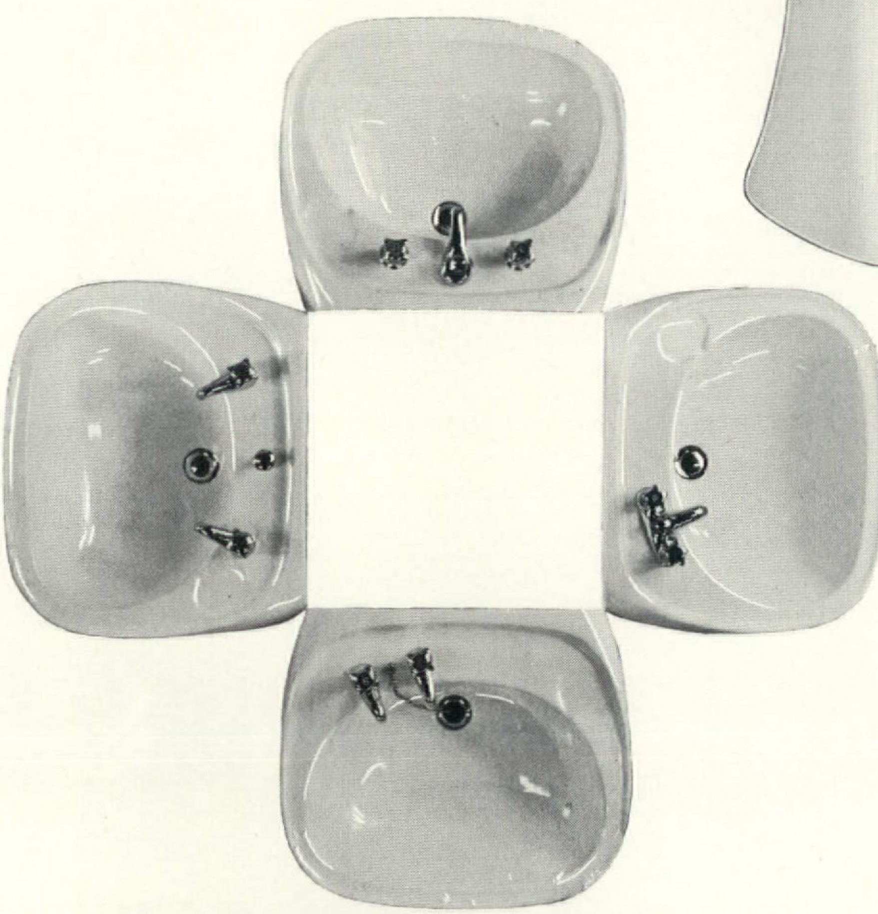
Earthenware basin on cast iron stand. Adams', 1897

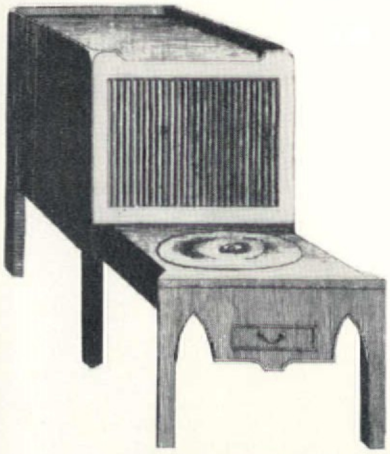
Pedestal basin, 1939



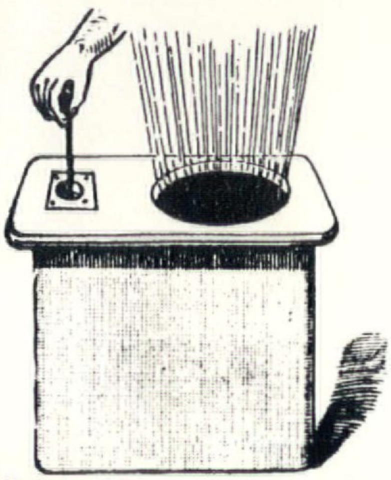
Basin with spraytap and soap dispenser, 1965

* Properties described in *Product Analysis, Water Closets, AD* November 1965

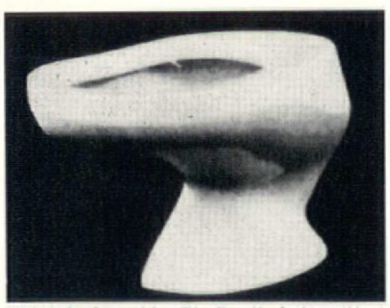




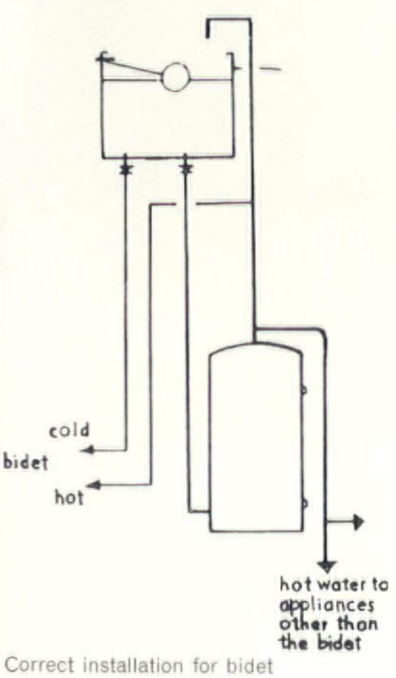
Night table with bidet, Heppelwhite, 1787



Victorian bidet



Bidet designed by Gio Ponti, *Aujourd'hui*, 1958



Correct installation for bidet

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The Building Regulations now firmly define the bidet as a waste fitting and it can, therefore, be connected to the main waste stack on a two-pipe system. The facilities offered by bidets vary considerably, and in its most rudimentary form comprises a low washing bowl supplied with water from a sufficiently high level to avoid the attention of water boards. But the more complex models with spray douche and flushing rim have a water supply inlet below the overflow level, and there is a danger (real or imagined) of back syphonage or gravity flow causing contamination of the water services. Most authorities require the bidet to be supplied from a cistern which, if feeding other fittings, must be 6ft above the bidet inlet. In low level distribution systems an alternative that may carry greater risk of back syphonage is sometimes acceptable; the cold supply pipe must rise for a height of 6ft before being led back to connect to the appliance. The risk of contamination of the hot water system is extremely slight and its possible effect less serious, so any arrangement similar to that indicated, with the branch located near the vent, should be satisfactory. Our water supply regulations may be more efficient than those in force on the continent but if we are to avoid their becoming the indirect cause of a lower standard of personal hygiene by inhibiting the increased use of the bidet, then there is an urgent requirement for a nationally accepted code confirming a standard installation practice.

Criteria for design
Lavatory basins

Personal variations in washing habits create differing requirements for lavatory basins, but if we exclude the special considerations for hairdressing, hospitals and schools, the basic criteria for domestic applications may be clearly stated and discussed.

Aesthetics

The basin normally forms part of a bathroom or is located on a wall in a bedroom; in each case it should be considered as a component forming part of a cohesive whole, unobtrusively and efficiently fulfilling its individual function. This function demands that the junction with the wall surface should be given sufficient consideration to achieve close integration. Occasionally the basin is treated as an individual item or grouped with another fitting, in which case it must be specifically treated as a free-standing item and not merely modified from a wall version. There is an increasing tendency for manufacturers to treat the basin as an unique element, occasionally as an isolated sculpture. Few attempts are made to integrate the basin with the surface to which it is attached, and none at all to regard it as a component forming part of a cohesive whole.

Economics, production and marketing

Manufacturers may consider that these three closely linked factors are problems on which they are better fitted to make judgments than the consumer, but they are profoundly influenced by consumer attitudes which can subtly stimulate reactions. Public taste—no less than that of the architect—tends to become disproportionately selective when offered a wider variety of choice. Thus manufacturer's attempts to capture wider markets by increasing their range of products have resulted in a profusion of types, actuating a vicious cycle which reduces potential production runs. A superficial survey reveals that there are at least 250 different models available, a factor that must have an influence not only on production problems but also on the size of market for each type, both of which must have an effect on the cost This may be attributable to a failure to establish a coherent and comprehensive design brief due to inefficient market surveys. The fully considered design will be based on the consumers' needs interpreted by acute professional analysis rather than by the shallow surveys of untrained observers. Furthermore it will satisfy a greater market and consequently alleviate the problems of economic production.

Function and mechanical performance

The basin should supply, at any desired temperature within the tolerable range, sufficient water, either running or static, from sources located in a position that enables the washing operation to be carried out quickly and efficiently. Whether as an integral part of the basin or as a separate unit, provision must be made for all the toilet impedimenta normally used, and if the unit is not designed solely for use with a soap dispenser, space must be incorporated for the storage of soap in such a way that it will dry off when not in use. Very few basins are provided with space for all the toilet accessories used whilst washing. Those manufacturers who have incorporated an area for these articles are unable to agree on the most appropriate side of the basin for its location—a dichotomous viewpoint that appears to preclude the consideration of space on both sides.

The problem of soap has never been solved. The manufacturers' answer is to provide either a flat sinking which turns it into a soft wasteful mess, or high ridges on which small pieces of softened soap eventually harden and can only be removed with effort. Many basins are provided with rims wide enough to reduce seriously the internal dimensions but too narrow to be used as a top for toilet articles. On too many models the design of the inside edge permits spillage when water flow is at full pressure. Rims with in-curving sections would reduce this possibility and would be well worth the slight production difficulties involved.

The design of the rear of the fitting requires special consideration as it must not only permit easy access to the supply and waste connections and provide adequate rigidity and concealment of fixings but must also achieve a smooth junction with the wall, eliminating the possibility of water lodgement. Consistent with the approach that deals with the basin as an isolated unit, this detail has received little attention from most manufacturers: if butted to the tiling, the radiused back edge of the fitting makes it difficult to avoid a small channel in which water splashes collect; if the basin is fixed back to the wall with tiles butted to the edges tile cutting is frequently made more severe by the introduction of capricious curves into the design. These problems can be overcome by employing a basin mounted clear of the wall, of which several types are available, although not all are particularly successful in preventing splashing to wall and floor areas behind the basin. The more normal installation usually requires the inclusion of a splashback, but no models are available incorporating this as an integral or integrated feature. There are obviously difficulties associated with production and transport, but these appear to have been overcome in 1908 and could possibly be solved by historical research. For public installations, where groups of basins are required, most manufacturers provide overlaps to link adjacent basins but these are often after-thought excres-

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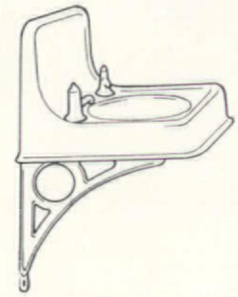
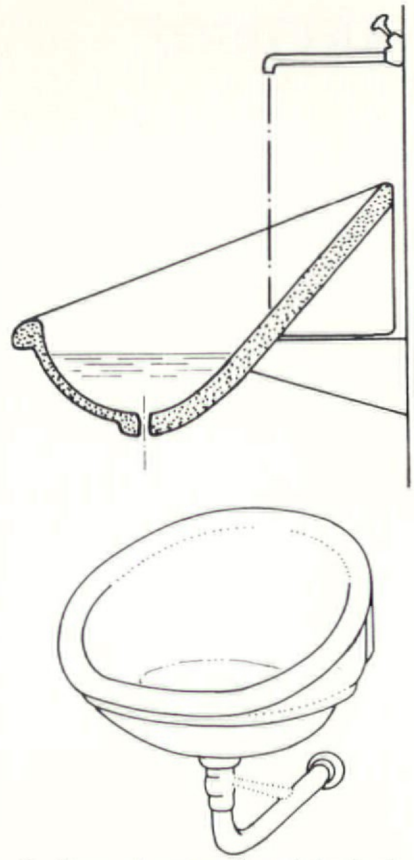
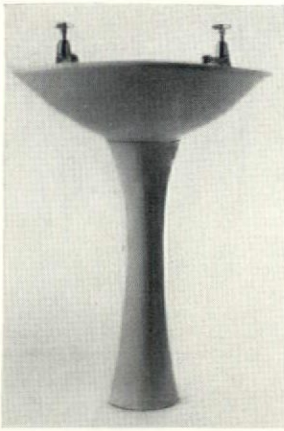


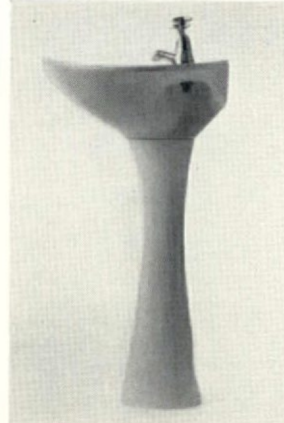
Basin and splashback, 1908

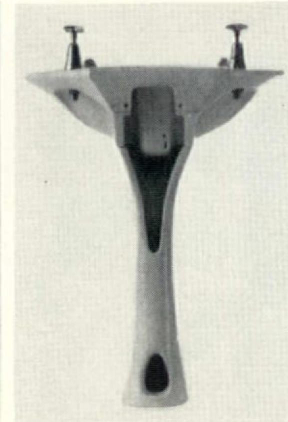


Section and perspective of basin designed by Alvar Aalto for Paimio Sanatorium, Finland, 1933. *Werk*, 1946

For those who feel that no lavatory basin totally satisfies their requirements, this simple alternative providing soap dispensers, and running water over a plate glass splashing plate in a laboratory at Amersham, may be more acceptable. Cleaning problems might be eased by raising the channel, which would also make the bottom edge of the glass less vulnerable to kicking. Designed by E. D. Jeffriss Mathews.







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cences, visually disatisfying and difficult to clean.

Ergonomics

Although varied for specific conditions, the range of use of the basin, in descending order of frequency, is for washing hands, face, body and hair. When installed in bed-sitting rooms it may also be used for washing clothing, but the increasing popularity of automatic laundries makes this a minor consideration. This, combined with the preference for washing hair under a portable spray now makes the provision of static water less essential than was formerly the case. If the basin is to be designed as an all-purpose fitting it must satisfy all these requirements to some extent, but bearing in mind the changing pattern of washing habits, must primarily conform with the requirements of the most frequent type of use.

Structural performance

The operation of washing invariably involves the movement over the basin of heavy items including bottles, tumblers, and razors, using wet and soapy hands. The material employed should be one which is highly resistant to impact damage, and will be unaffected by any acid or alkaline solvents or medicines that might be splashed, or even poured into the basin. With a few exceptions, most manufacturers are totally committed to the use of the traditional materials that only partly satisfy these requirements and are more concerned with using ceramic ware to make some sort of wash basin than with investigation of materials and methods or producing better basins.

Bidets

Due to our lack of experience in this country, design criteria for bidets are more difficult to lay down—as examination of most of the marketed types reveals. Nevertheless, certain essential design considerations can be formulated:

Aesthetics

The floor mounted bidet poses design problems similar to those for the WC and it is not surprising that current models reveal the same faults. Floor and wall junctions are given insufficient attention, and the special problems associated with the waste and spray mechanisms are in most instances not considered at all, leaving the fitting ostrich-wise with its most unattractive features fully exposed to view. In general the form of the bidet is based on studied amendment of precedent examples and has no regard for shapes determined by accurate analysis of function.

Economics and marketing

The rare use of the bidet confers on it a status value that supports a high price—a situation that manufacturers may seek to maintain but which provides little scope for fostering widespread acceptance. The range of types available is already too great for the demand, but before the situation gets out of hand, the

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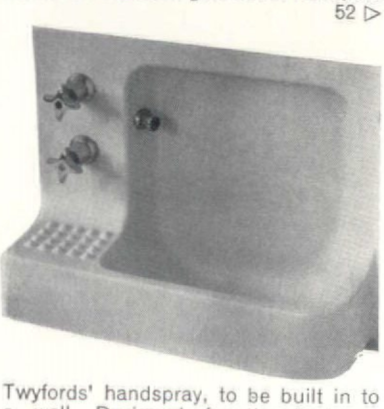
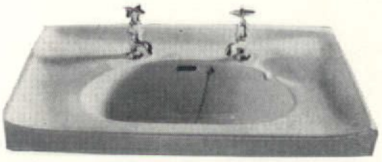
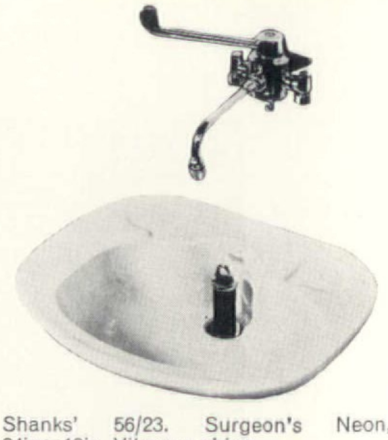


Twyfords' handspray, to be built in to a wall. Designed for the Barbican development

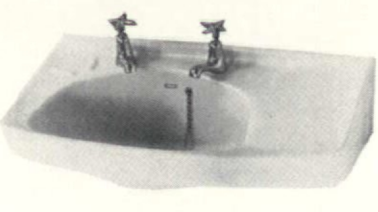


Goslett's SL1004 Spacious, 31in×19in. Designed by Wallis Goslett

Shanks' G57/17. Protos 28in×21in. Vitreous china

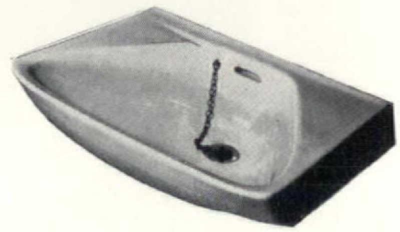


Shanks' 56/23. Surgeon's Neon, 24in×19in. Vitreous china

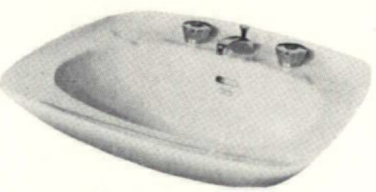


Twyfords' 14002/1 Albany, 28in×16in. Vitreous china. Designed by E. S. Ellis

Twyfords' 2662/1 Sola, 20in×16in, 23in×17in. Vitreous china. Available with pedestal



J. & R. Howie Ltd., 3737 Pelican 22in×16in. Vitreous china



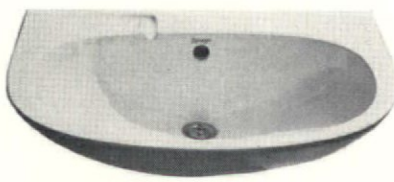
Shanks' 64/24 Clarendon 24in×20in, 27in×22in. Vitreous china. Available with pedestal

Armitage V4148 Meritex, 15in×13in, 20in×18in. Vitreous china

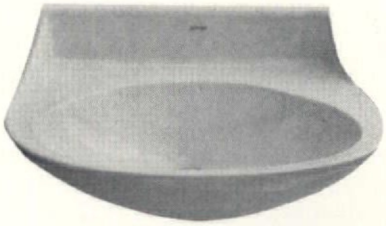
J. & R. Howie Ltd., 3714 Swallow, 24in×10in. Vitreous china. (Shown fitted with Unitap)

Adamsez 1187 Lotus-Spiral, 22in×17in. Fireclay

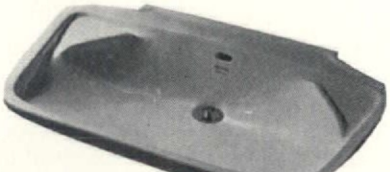
Lilleshall Sculptura 23in×17in. Fireclay. Designed by the Marquess of Queensbury



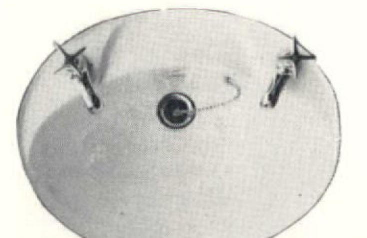
Adamsez 1137 Meridian One, 24in×18½in. Vitreous china. Designed by Knud Holscher and Alan Tye



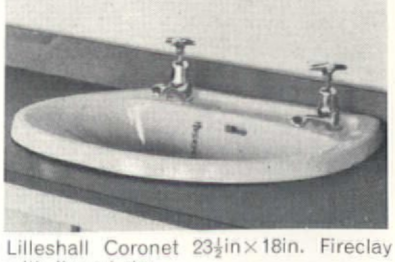
Adamsez 1134 Lotus surgeon's basin, 25in×18in. Fireclay



Adamsez 1197 Orchid. 28in×20in Fireclay



Adamsez 1161 Table-Lotus, 22in×17½in, 17½in×14¾in. Fireclay with unglazed rim.



Lilleshall Coronet 23½in×18in. Fireclay with lipped rim

Shanks' K58/58 Cavendish, 20in×18in, 24in×20in. Vitreous china table-top fitting

Twyfords' 2658/1 Vanity, 21in×17in. Vitreous china table-top fitting

Photograph by courtesy of D. S. Associates (a member of Allied Industrial Designers.)

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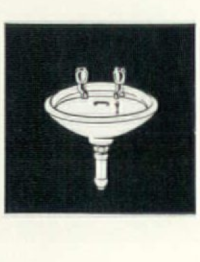

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BARBOUR INDEX 386

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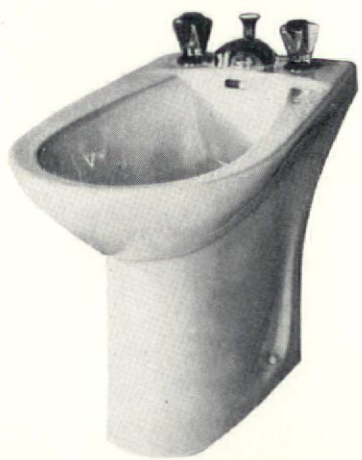
Twyfords' 2707/2. Vitreous china. Supply to bowl only, chain and plug waste

Steventon's Royal Venton bidet. Vitreous china. Diverter to rim or spray, pop-up waste

Shanks' K62/68 Curzon. Vitreous china. Diverter to rim or spray, pop-up waste

Twyfords' 2706/1. Vitreous china. Diverter to rim or spray, pop-up waste

Armitage V1001S Oriana. Vitreous china. Diverter to rim or spray, pop-up waste



Armitage V1005C Orima. Vitreous china. Supply to bowl only, pop-up waste

Armitage V1002 Ortrina. Vitreous china. rim or spray, pop-up waste

Ideal-Standard Kingston. Vitreous china. Diverter to rim or spray, pop-up waste

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opportunity exists for an enlightened firm to concentrate their energies on the design, production and marketing of one well considered model capable of being sold at a price that would make an assault on the larger market.

Function and mechanical performance

Compared to the lavatory basin, the similarity of function demands almost identical, but rather more specialized, considerations. The hands are not only fairly resistant to high temperatures but are also highly mobile, and are, therefore, not very susceptible to scalding if the water is too hot. The region covered by the bidet spray, being very much more sensitive and extremely unmanoeuvrable demands a mixer fitting on which the temperature can be pre-set and continuously maintained. In spite of this, some models have inadequate temperature control mechanisms which can be the cause of quite uncomfortable experiences.

The waste mechanism must not be so complicated that it becomes uneconomic, but must avoid the necessity to immerse the hand in dirty water in the event of failure. No designer appears to have produced a rational compromise between the unsuitable plug and chain and the expensive pop-up waste.

Ideally the section of the rim with which the user is in contact should be permanently warmed, or at least capable of being heated very quickly. It is difficult to imagine the appropriate use being made of any versions that do not incorporate this.

Ergonomics

The ideal bidet should have a bowl of sufficient frontal width to provide a seat for the user and contoured, appropriate to the height, to transfer pressure to the buttocks. The back of the bowl should be of ample width to permit the handling of soap etc., without spilling. Most models fail to incorporate either of these features and it is doubtful whether more than one version adequately satisfies both conditions.

Perhaps due to its origins as a portable unit and similarity to the WC, confused thinking on the subject has become established, resulting in the reversal of the ideal ergonomic shape. Most have a wide seat area tapering to a narrow back, which not only constricts the area where the hands are in motion but also creates a rim outline producing a diagonal pressure area across the underside of the thighs. This combined with an entirely inappropriate seat shape can cause conditions of acute discomfort.

Production and structural performance

The traditional materials employed for bidets can be the cause of wastage in production which must reflect itself in the cost. The design of new models fails to exploit the possibilities of new materials that might satisfy the requirements of both economic production and structural performance.

Manufacturers' approach

Do the manufacturers of these products make accurate assessments of the market requirements, and by what methods? What degree of consideration is given to design, and is there a common basis (or indeed, any basis) for design? In an attempt to obtain broad and comprehensive answers to these and related questions, enquiries were sent to forty manufacturers of sanitary fittings. Replies were received from only six firms, but as these were made on the clear understanding that the information was to be employed for a critical analysis, the response although disappointing, was very positive in revealing those

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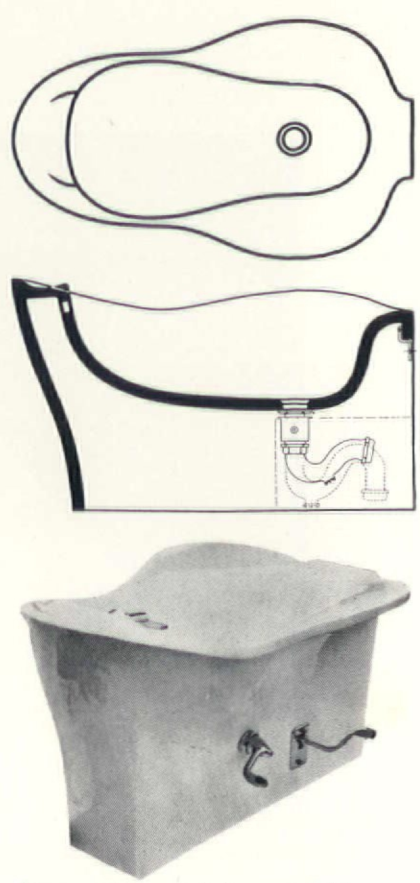
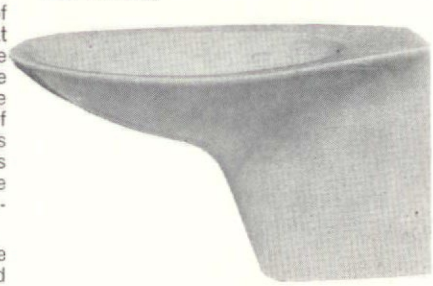
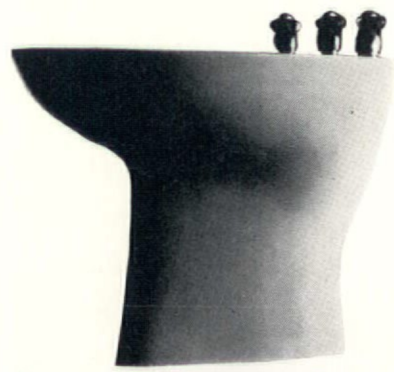


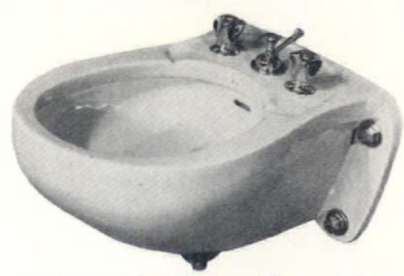
Plan, section and photograph of Adamsez Lotus K line maternity bidet. Pedal control. Fireclay



Adamsez 1138. Meridian one. Fireclay. Designed by Knud Holscher and Alan Tye



Doulton's V3310. Vitreous china. Designed by Derek Woolliscroft. Diverter to rim or spray, pop-up waste



Armitage V1006 Ormura Vitreous china. Wall hung fitting, diverter to rim or spray, pop-up waste

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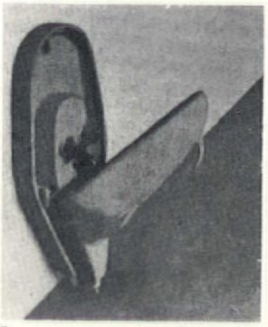

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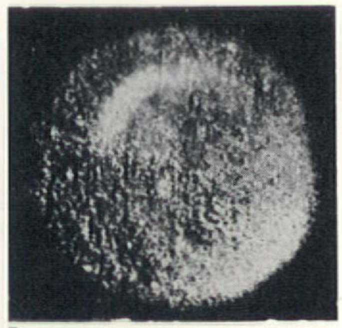

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Free-standing basin designed by Charlotte Perriand, *Aujourd'hui*, 1958
2 & 3
Tipping bidet by Giulio Minoletti. Designed to save space and 'make less obtrusive the embarrassing object that the Anglo-Saxons consider to be shocking'. In several combinations of vitreous china and vitreous enamelled steel. *Domus*, 1952
4 & 5
Buckminster Fuller's experimental fog gun and microphotograph taken of the skin pores to determine efficiency

Some makers of lavatory basins and bidets

*Adamsez Ltd., 75 Victoria Street, London S.W.1.

*Armitage Ware Ltd., Armitage, Rugeley, Staffordshire.

*Doulton Sanitary Potteries Ltd., Whieldon Pottery, Stoke-on-Trent.

*Alfred Goslett & Co. Ltd., 127–131 Charing Cross Road, London W.C.2.

Heathcote Ceramics Ltd., Calvin Street, Longton, Stoke-on-Trent.

J. & R. Howie Ltd., Hurlford Works, P.O. Box No. 13, Kilmarnock.

Ideal-Standard Ltd., Ideal House, Gt Marlborough Street, London W.1.

Johnson & Slater Ltd., Queenborough, Kent.

*The Lilleshall Co. Ltd., St George's, Nr Oakengates, Shropshire.

Shanks & Co. Ltd., Tubal Works, Barrhead, Glasgow.

Shires & Co. (London) W.10. Guisley, Yorks.

John Steventon & Sons Ltd., Royal Venton Works, Middlewich, Cheshire.

*Twyfords Ltd., P.O. Box No. 23, Stoke-on-Trent, Staffordshire.

*_The co-operation of these firms in providing background information is gratefully acknowledged._

◁ 52

firms whose attitudes to design were clearly defined and whose frank replies gave evidence of conscientious assessment of requirements and a sincere attempt to improve the standard of design and quality of their products. It would have been even more positive if it could be demonstrated that these attitudes had resulted in a range of consistently excellent designs, but this is, unfortunately, not possible. Some of the faults are embodied in the designs of all manufacturers, and the criticism can be applied to the industry as a whole.

The aim of our analyses is to offer a constructive criticism of both product and user that can only result in better products for the consumer and more success for the manufacturer; it is hoped that those firms who have co-operated by providing information will appreciate that the level of this criticism can only begin with the better standards of design that their products represent.

Most manufacturers give precedence to function and structural and mechanical performance, with wide individual variations in the order of priority for other design criteria. For the bidet, however, the definition of the major design criteria becomes slightly blurred, due no doubt to the circumstance that the users often have an imprecise idea of the requirements they expect the apparatus to fulfil.

Criticism

Lavatory basins

Basins available today represent a very limited advance from the products in use in 1890. Aesthetically they are worse.

Most manufacturers are earnestly attempting to improve their designs, but design is constricted to a narrow field and consists of constant refinement and gradual improvement of well established principles. In functional products of this type the process can only be continued up to a specific stage, beyond which further work produces self-conscious designs with an independent aesthetic divorced from function, and the designers' brief is automatically restricted to a wash basin rather than a means of washing. No encouragement to a broader viewpoint is given by the consumer. For some reason the bathroom has always been a favourite location for the display of status, either *per se* or, after its universal acceptance, by the elaboration of equipment. This is perhaps the explanation for the meaningless and obstructive pedestal that is still so popular but which is in most cases purely vestigial. If it has a design function it is to conceal the examples of plumbers 'virtuosity that in one form or another adorns most bathrooms.

The demands for unique and assertive designs coupled with the requirements of British Standards create an ambivalent situation which places the designer in an unenviable position, but does not mitigate his failure to acknowledge certain basic functional conditions. It must be generally realized that whether spray taps, pillar valves or mixer fittings are used, people wash most frequently in running water, yet outlets are still located too near to the back edge of the basin to enable this to be performed effectively. The basin is primarily for the removal of dirt and although the possibility of fouling should be minimized it must be capable of being simply and quickly cleaned. This obvious fact is often entirely overlooked. The positions of tapholes almost invariably creates spaces beside or behind the taps that are difficult to clean, a problem aggravated by the junction between the tap and the basin and the level of the outlet. The standard concealed overflow has never been hygienically satisfactory and in some designs can acquire a most gruesome interior. A number of basins are available with the standing waste which eliminates this problem and provides a cheap alternative to the archaic waste plug. Where this is not available there is little excuse for not supplying, as a standard item, a waste plug with disappearing chain.

The spray tap represents a considerable step forward as a washing facility, and its successor, the timed spray, will provide an even higher standard of personal hygiene. No manufacturer has yet exploited the latent potential of this device by achieving close integration with a specially designed basin. All the models available are merely conventional basins with modified punchings.

Bidets

Before attempting criticism of the general standard of design of the bidet it is necessary to make some apportionment of the blame for the bad features that exist. The market for bidets is so small that the designer is deprived of the feedback from a large body of consumer opinion that is so necessary for the continued development and improvement of any product; on the other hand, he is freed from the design restrictions produced by public preconceptions—a situation frequently encountered when attempting to introduce innovations in a firmly established article.

The public attitude towards the bidet varies between mistrust and humour, and as one manufacturer complains: 'Because it is almost universal in France and on the continent, the bidet has acquired an image that is slightly immoral, and is also regarded as being used by dirty people.'

This contrast between the continental and Anglo-Saxon approaches to hygiene is exemplified by the fact that whereas it is normal for an Englishman to wash his hands after urinating, the Frenchman will usually wash beforehand.

However, our failure to appreciate the advantages of the bidet (which are claimed to include not only the alleviation of skin irritations and minor internal disorders, but also relief in the treatment of haemorrhoids, pruritus, and eczema) does not justify the design approach which lavishes much attention on attempts to create a clean, free-standing sculptured element yet leaves the supply pipes, spray and waste controls in uncontrolled disarray at the rear. To draw these elements together to form an organized group as a frank expression of their function would be commendable; to leave them to the not so tender mercies and aesthetic sensibilities of the average plumber is unpardonable. Where the appliance is designed to fit flush with the wall this problem has been overcome, but there is still a failure (except in one instance) to relate the profile to the tiling grid. No doubt the present small market has induced manufacturers to reduce the cost by offering reduced facilities, but the range of products now available under the name of *bidet* varies from equipment with a thermostatically controlled adjustable spray and heated rim, to a simple low-mounted bowl with hot and cold supply taps fitted to the wall above. This type of fitting barely qualifies as a bidet and serves little better than a lavatory basin.

The future

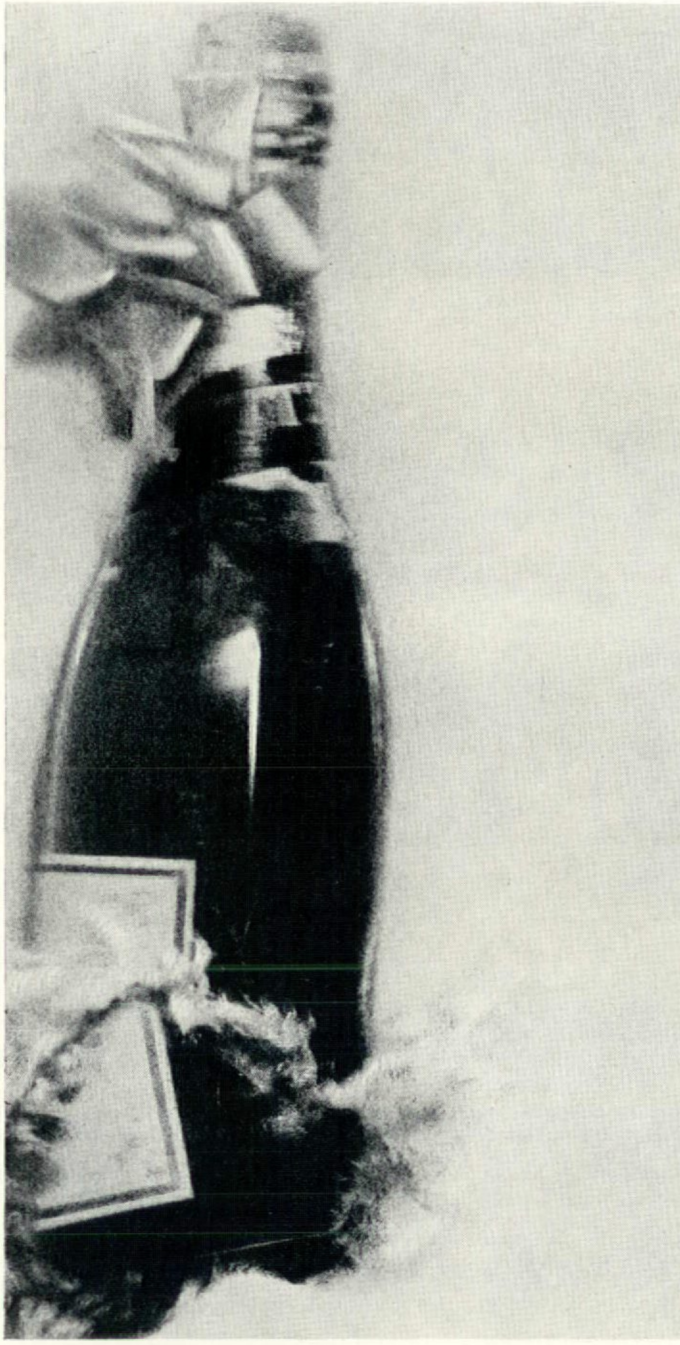
Advances in the design of lavatory basins have been so slow that the broader concept of a design technology providing a new method of cleaning the body seems remote.

The most promising process investigated in the last twenty years is now languishing. Buckminster Fuller's fog gun, developed as part of his programme for an autonomous house, develops to a finality the principle of the spray tap which has demonstrated that, provided it is applied in a suitable way, far less water is needed for washing than is normally supposed. Fuller's invention employs a jet of atomized water fed with solvents and delivered at high pressure, not only to clean the surface of the skin but also to remove dirt from the pores. It utilizes the principle that if applied in the form of vapour or minute droplets, the water will evaporate very rapidly, and the dirt carried from the surface of the skin will settle as dust. The vaporization of the water enables far smaller quantities to be employed and it is claimed that a pint of water applied in this way is sufficient for a bath lasting one hour.

It requires little imagination to visualize the impact on bathroom design that might result from the marketing of this device: as it requires no connection to a drainage system the distinction between taking a bath and using a wash basin would become meaningless, and either operation could be performed in any bedroom.

Whether the particular cleaning problem solved by the use of the bidet could be carried out as hygienically and comfortably by the use of this mechanism raises some doubts, and would obviously require some investigation.

If we must retain an outworn system whilst waiting for the introduction of a new method, let us not be content with the occasional revivification of the image by slight changes that lack significance. Only by stringent criticism coupled with keen discrimination before selection, and forceful complaint against goods that fail to satisfy functional criteria, can manufacturers be forced to improve the standards of their products. In this connection architects must share some responsibility; failing to make regular visits to their buildings over a long period to gauge the performance of the products used, they rely on transmitting complaints from users whose critical faculties are not as developed as they might be. More to the point, they may be less severe than those of the next client for whom the same products are specified.



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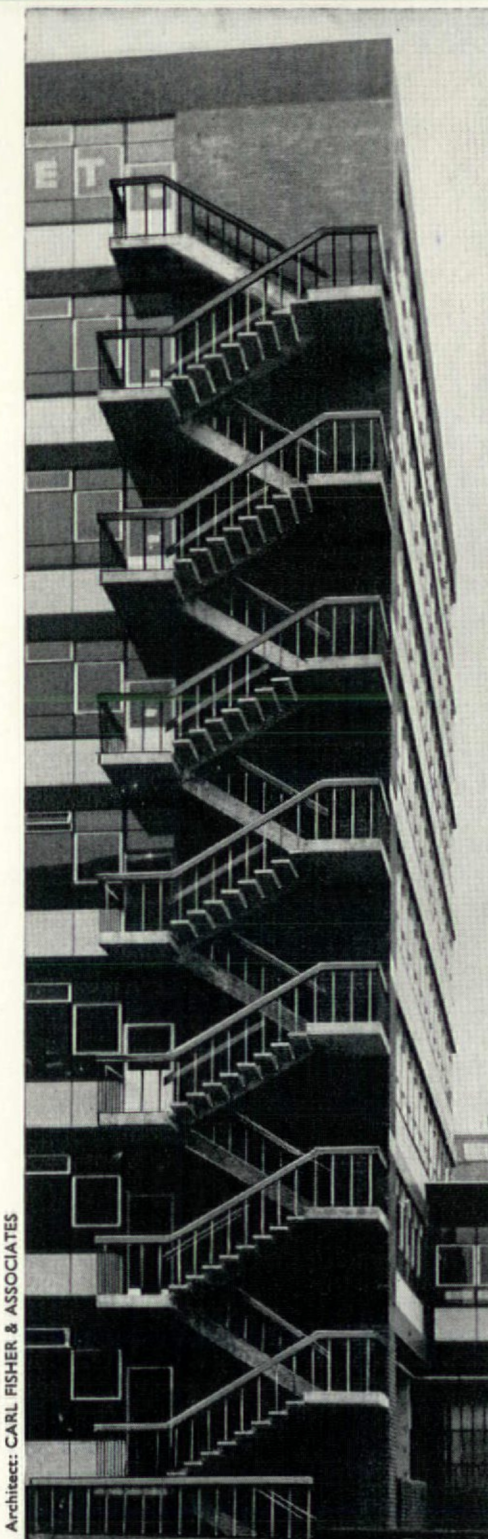
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Trade notes

Alexander Pike

To obtain additional information about any of the items described below, circle their code numbers (G1, G2 . . . etc.) on the Readers' Service Card inserted elsewhere in this magazine.

G1 Nylon hinges

James Collins (Birmingham) Ltd.

Rising hinges made from injection moulded black nylon with precision ground stainless steel pins. Size 3in × 2⅝in.

G2 Notice boards

James Walker & Co. Ltd., Lion Works, Woking, Surrey

Backed with a composition of cork and rubber and faced with Hypalon synthetic rubber in which holes close after pins have been removed. The smooth surface can be wiped clean with a cloth. Standard sizes 3ft × 2ft, 3ft, 4ft, 5ft, 6ft and 7ft.

G3 Plastics bowl urinal 1

Sovereign Building Components Ltd., No. 2 Works, Sydney Road, Watford, Herts.

Moulded in acrilonitrile-butadiene-styrene. Weight 2¼ lb, price £5 10*s* excluding fittings.

G4 Glazing insulation

Wilmshurst Bros. Ltd., North Wing, New England House, Nr. Preston Circus, Brighton, 1, Sussex

A sheet of Melinex polyester film housed in a 2in × 2in metal box at the window head operates on the roller blind principle and slides in white plastic guide rails. Sizes up to 8ft × 4ft 6in and 5ft × 9ft. Price ranges from 6*s* 0*d* per ft².

G5 Two colour diffuser

Richard Daleman Ltd., Latimer Road, London W.10

Manufactured by coupling two extruders into a common die head; this prismatic diffuser controls the intensity of light downward in the 60° zone and is claimed to provide approximately 20 per cent greater light output than ordinary single colour opal diffusers. In 4ft, 5ft, and 8ft lengths.

G6 Gas fired central heating 2

Radiation Central Heating Ltd., Radiation House, 255 North Circular Road, Neasden, London N.W.10

The Radiation Heatmaster gas-fired small bore central heating unit has an output of 45,000 B.Th.U. and combines fast heating up with sensitive control. Overall size: 36in high, 25in wide, 16in deep, but without casing will fit under kitchen work top; Prices: Standard model £106 4*s* 0*d*. Balanced flue model with press-button ignition and clock control £130.

G7 Mechanized file storage

Frank Wilson (Filing) Ltd., Cross Street, Southport, Lancashire

Filing racks on an electrically controlled vertical conveyor enable the Railex Rotomatic to place the equivalent of 62 filing cabinet drawers within reach of a seated operator. Control is by push buttons and the machine occupies a floor space 4ft × 6ft.

G8 Locks for narrow stile doors

Architectural Hardware Ltd., Royton House, 14–17 George Road, Edgbaston, Birmingham 15

A range of one-, two- or three-point deadlocks for narrow stile swinging or sliding glass doors.

G9 Automatic sliding and swinging doors

Architectural Hardware Ltd., Royton House, 14–17 George Road, Edgbaston, Birmingham

Automatic door gear combining sliding and swinging action for single doors up to 4ft wide or double doors up to 8ft wide.

G10 Cable and conduit saddles 3

Herzbi Ltd., 57 Lordship Park, London N.16

Fischer saddles are moulded in nylon with flexible tongues to secure the cables. Interlocking lugs and a concealed clipping system provide neat installations and suggest that their use might be extended for plumbing where pipework is exposed.

G11 Faster tiling

Pilkingtons & Carter, 42 Bloomsbury Street, London W.C.1

Jetfix sheets contain twelve 6in × 6in × ¼in tiles taped together at corners and edges and are fixed as a complete unit 24in × 18in.

G12 Surfaced asbestos sheets

Turners Asbestos Cement Co. Ltd., Trafford Park, Manchester 17

Colourbest fully compressed asbestos-cement flat sheets are surfaced with a polyvinyl fluoride film claimed to be capable of stretching and recovering and to resist chipping, cracking and crazing. Sheet sizes up to 10ft × 4ft in eleven colours.

G13 Window ventilators 4

Argosy Engineering Co. Ltd., Hertford Road, Barking, Essex

Measuring only 2in deep and suitable for single or double glazing the ventilator has a vane pivoting on nylon bearings and can be controlled to any intermediate angle between the fully open and closed positions.

G14 Pre-felted wood wool slabs

British Gypsum Ltd., Fergusson House, 15–17 Marylebone Road, London N.W.1

Gypklith roofing slabs are now obtainable with a layer of fibre based roofing felt bonded to the upper surface. Available under the name Dri-dek at a surcharge of 2*s* 3*d* per sq yd.

G15 Air diffusers

Van den Bosch Ltd., Europair House, Alexandra Road, Wimbledon S.W.19

Suitable for inlets or extracts on walls or ceilings, polypropylene diffusers of 4in, 6in and 8in diameters in ivory white finish. Prices 29*s*, 34*s* 6*d*, 45*s*.

G16 Prefabricated ducting

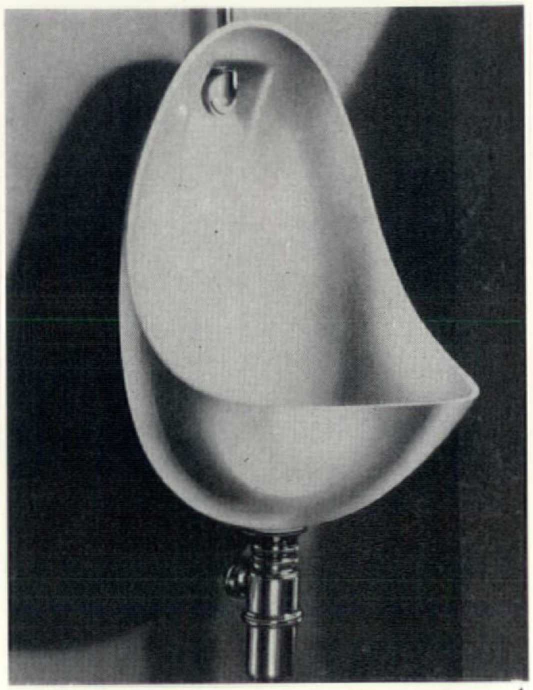
Fibreglass Ltd., St. Helen's, Lancashire

A lightweight fibreglass duct combining thermal and acoustic efficiency with labour-saving adaptability. Installation claimed to be cheaper and faster than traditional materials lagged to an equivalent standard.

G17 One-way view fabric

Metalon Gesellschaft, Fonnenallee 122, Berlin-Neukoln, Germany

Produced by the vapour deposition of aluminium, silver or gold on one side of any fabric containing synthetic fibre. When used for curtains the resultant material is either transparent or opaque according to the side from which it is viewed.



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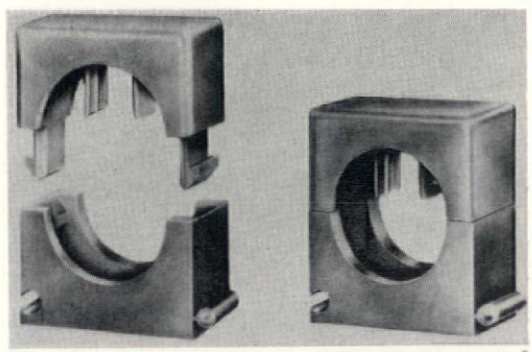

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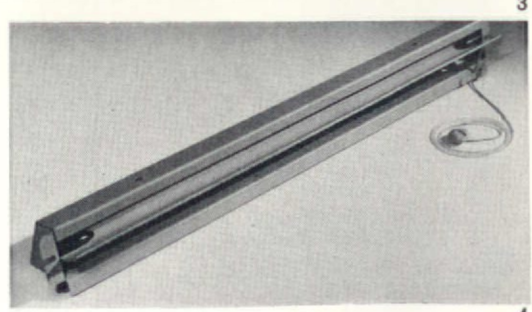

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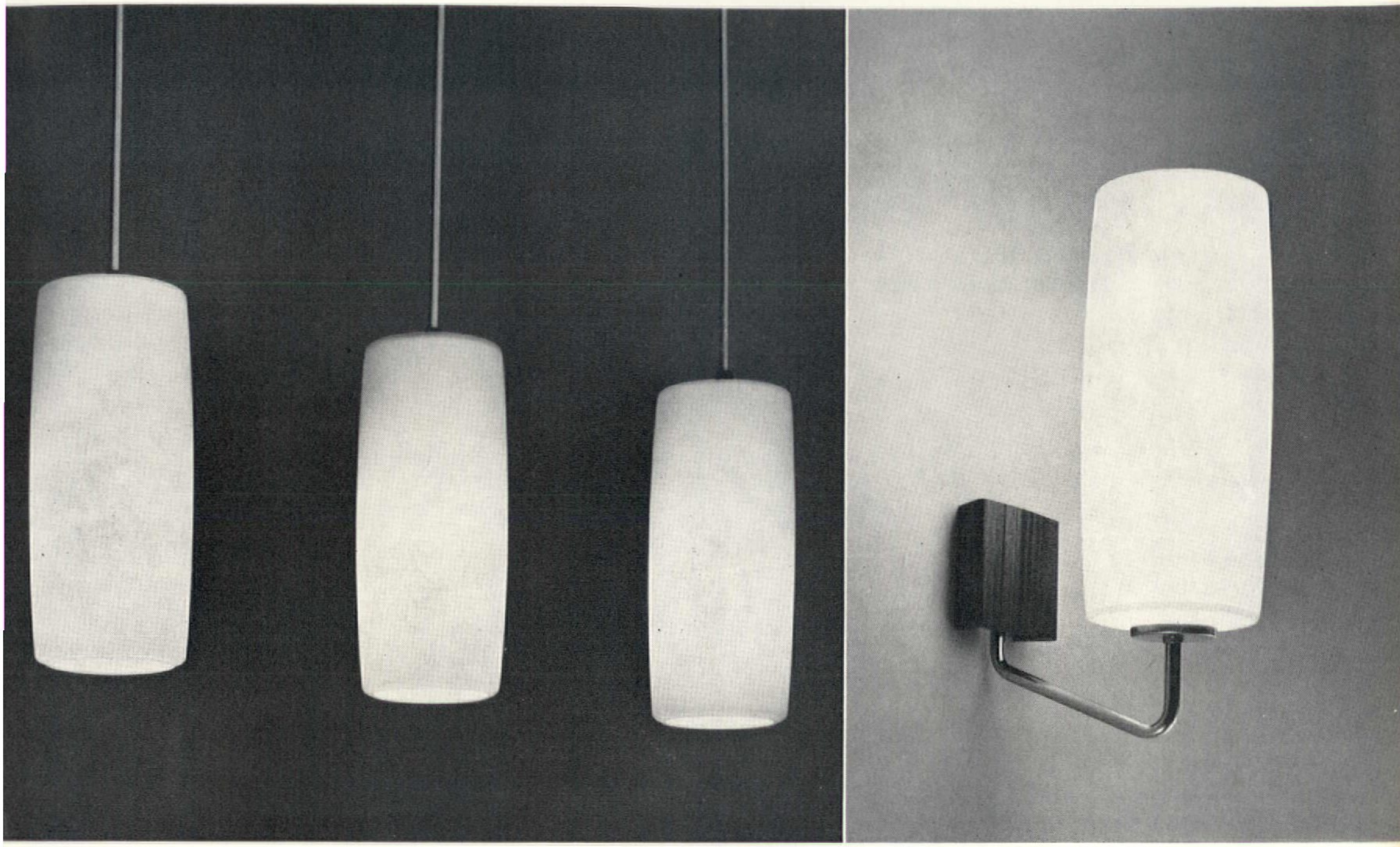
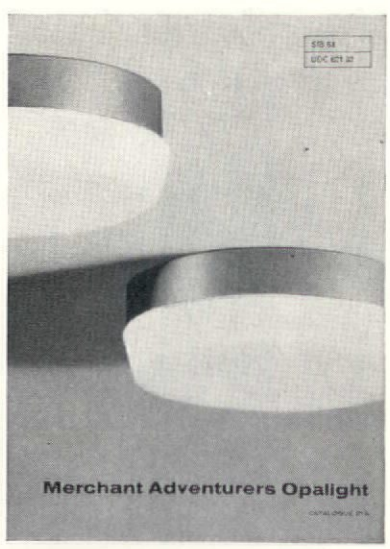


Versatile 1620 series single and multilight units from Opalight catalogue 21A



Opalight 21A

This publication illustrates with photographs, dimensional drawings and prices, some 450 MA lighting fittings using opal glass diffusers and provides an indispensable guide to the best ranges in Opal lighting today

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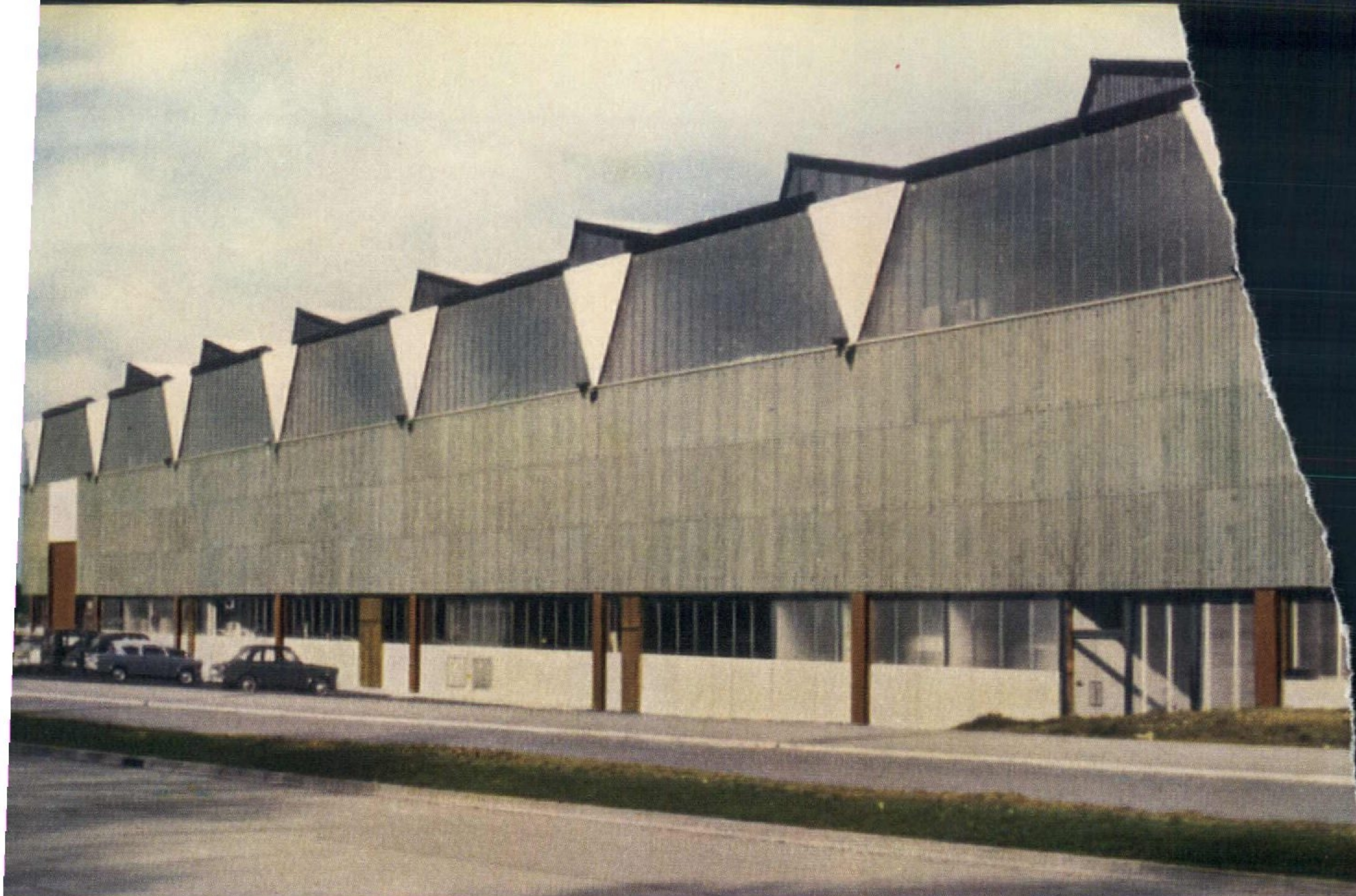

FOR INDUSTRIAL BUILDINGS THAT WORK BETTER
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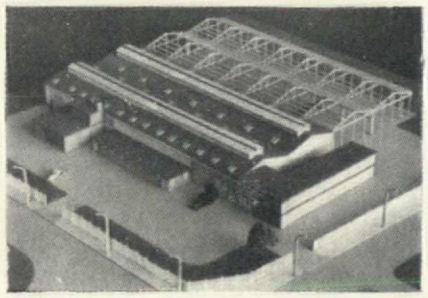
Adaptable Industrialised Systems—factories from the factory

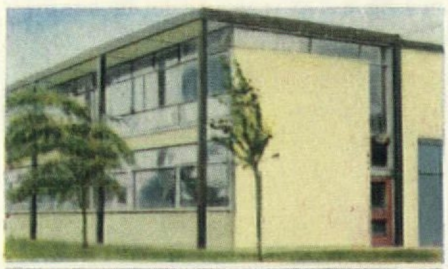
'S & F' steel-framed 'Clearportal System. An example of standard steel construction that is easily adapted to specific needs.

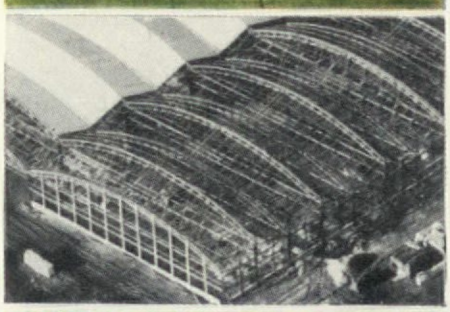
An economical Atcost 'S'-frame warehouse. Standard portal frame design easily adapts to various needs, cutting design overheads and speeding erection.

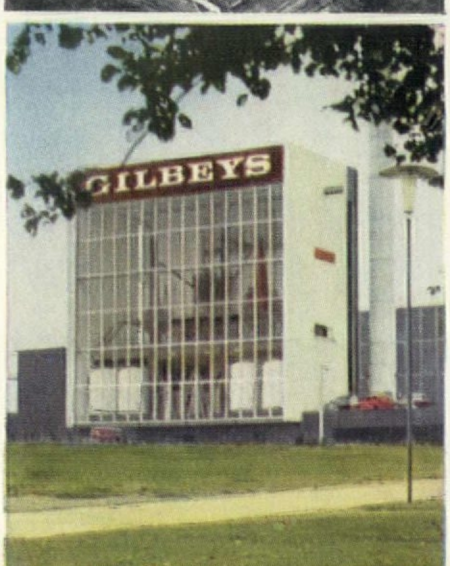


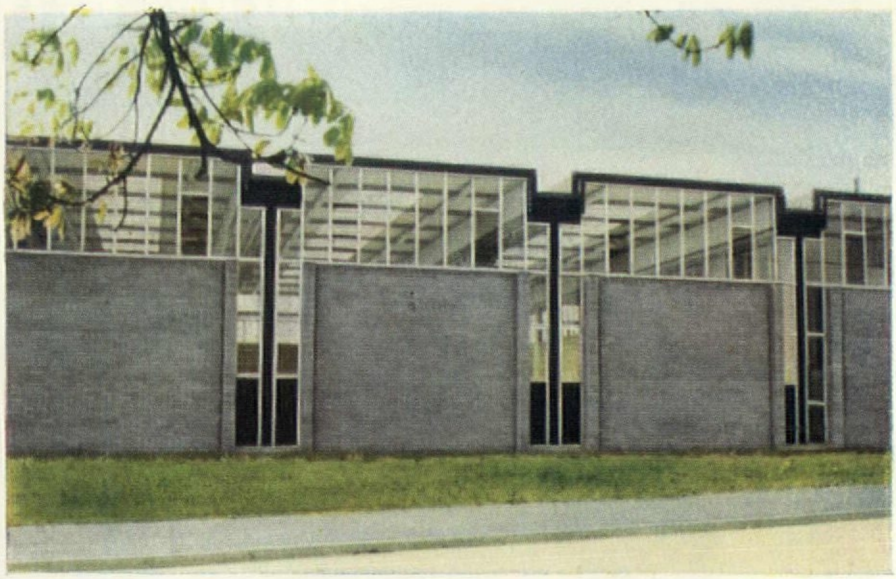
Easily adapted standard factory. Steel framed and clad 'Advance' unit of the Industrial Estates Management Corporation for England. Flexibility of structural steel is unique in permitting the required ease of expansion or adaptation for changing needs.

Designed-for-purpose projects—planned faster, erected sooner









This attractive lightweight steel frame and roof design permits lighting of a high order—both natural and artificial—to meet the needs of exacting machining tolerances.

Top left: Neatly-designed : an attractive all-welded exposed steel frame effectively links this 2-storey office to the adjacent tubular steel-framed workshop.

Middle left: Steelwork for the big new Cambridge University Press printing works, with curved clear spans of 144 ft, had the advantages of being lighter and needing cheaper foundations, and was faster to erect, less dependent on weather than alternative methods.

Bottom left: Structural steel was used for the entire superstructure of this outstandingly-designed project; a glass-walled distillery, warehouse and multi-storey administrative buildings.

See further examples of steel industrial buildings on the rear page of this inset

This new steel framed and clad VC 10 hangar at Gatwick can house three BUA aircraft types simultaneously. Four 191-ft cantilever truss girders with 134-ft overhang give 33,000 sq ft floor area with only two internal columns. Steelwork design provides for future expansion. (*Cover photographs*): A good-looking building—a good environment for better work. Aesthetically pleasing and functional factory design with steel frame and monitor roof structure cleverly arranged to integrate various cranage and overhead services, and give bright, pleasant, ordered working space.

STEEL for speed and economy in building for industry

Superior speed of construction, and progress independent of the weather, are among the many important advantages and major economies now being gained by using structural steel for single and multi-storey industrial buildings of every kind. Steel frameworks can be more easily and quickly erected using standard, lightweight sections and ready-fabricated building components. The relative lightness of individual steel members permits useful additional economies, both in transport and on the site. When covered space requirements include large uninterrupted floor areas, strong, lightweight roof structures in steel provide by far the widest clear spans available economically.

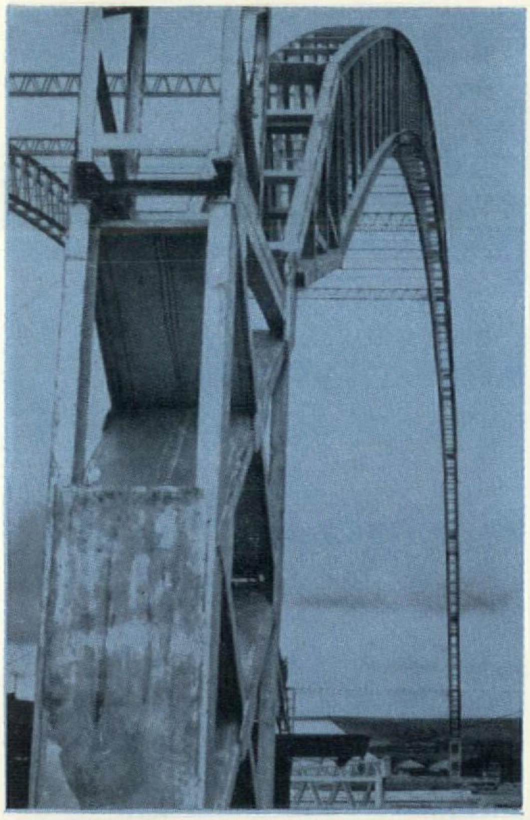
Factories in steel: designed faster—in production sooner The decision to build with steel means less time is required in design and detailing work, either for adapting a standard steel 'system' building, or creating a purpose-built structure. Steel gives the advantages of fast, dry construction. Because it is an easily fabricated, precise and accurately calculable constructional material, it gives assistance to the designer at all stages in the present-day quest for better, lighter, more adaptable and architecturally pleasing buildings, that will both cost less and be better designed for better work.

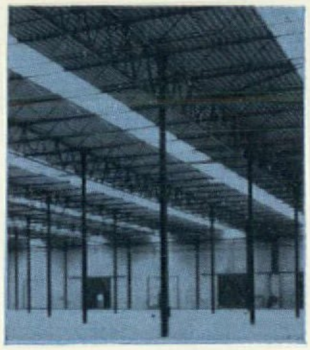
Adaptable buildings for rapid expansion at minimum cost Better factories that can make useful contributions to Britain's export drive are urgently needed. In all government-financed industrial estates, steel-framed construction is meeting the need: chosen invariably for its advantages in cost, speed, adaptability, ease of future extension.

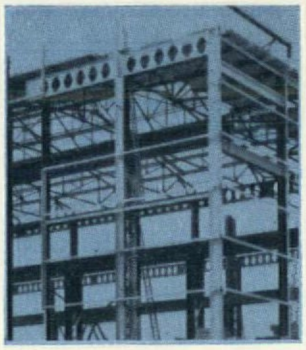
Steelwork progress —for better factories, warehouses, and industrial structures

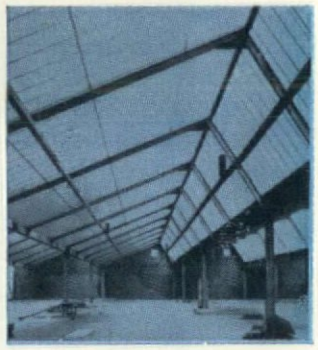
Many recent technical developments in the structural steelwork industry have yet further increased the advantages of building, extending, or modernising, factories and other industrial structures in steel. The rationalised range of Universal rolled sections; strong lightweight, versatile structural hollow sections (SHS) in many profiles; improved welding techniques; friction-grip bolts that eliminate site welding or riveting; better, faster erection techniques—those are just some of the important contributions made by steel to lighter, better building at less cost.

Quickly-erected 'Arcon' steel-framed and clad multi-span vehicle parts depot. Lightweight roof structure employs tubular steel SHS. The 40-62 ft interval steel columns give clear floor areas for orderly storage and goods handling.









Left: A large-span warehouse. Steel arches of 250 ft clear span provide 100,000 sq ft of totally unobstructed storage area.

Above left: Clean, light, easily-maintained tubular steelwork gives high stacking space for forklift trucks, in this modern warehouse. Rainwater pipes carried inside hollow steel columns are safe from accidental blows.

Above centre: Progress on Britain's most modern integrated car production plant. Steel frame and northlight roof are designed to carry complex overhead services. Lightweight 'Castellated' beams cut structural weight and cost.

Above right: Factory extension with light, economical structural steelwork based on the plastic design theory. Slender steel framing gives more effective utilisation of floor space and better roof lighting.

REFERENCES **Cover** Basildon New Town factory for York Shipley Ltd. by Arup Associates, Architects & Engineers. **Inside pages** British United Airways VC10 hangar, Gatwick, Architects: Clive Pascall and Peter Watson. Factory premises for Walter Jones & Co (Engineers) Ltd and workshop/office for CIBA (A.R.L.) LTD designed by Arup Associates, Architects & Engineers. New Cambridge University Press printing house, Architects: Beard, Bennett, Wilkins and Partners; Consulting Engineers: Frederick S. Snow and Partners. New Harlow premises of W. & A. Gilbey Ltd, Architect: John Timpson of Peter Falconer and Partners. Consulting Architect: Alexander Gibson. General Constructors: Holland & Hannen and Cubitts Ltd. 'Clearportal' building by Sanders & Forster Ltd for Canterbury Industrial Products (Aveley) Ltd, Architects: Carr, Goldsmith & Fallek. 'S'-frame warehouse for H. P. Tyler Ltd by Atcost Ltd. 'Advance' factory unit by Industrial Estates Management Corporation for England. **Rear page** Storage depot for Ford Motor Co Ltd, Parts Division, designed and constructed by Taylor Woodrow (Arcon) Ltd. Steel-arch warehouse at Newhaven, designed and erected by Fromson Construction Co. of Canada, Byfleet, Surrey. Kitt Green warehouse for H. J. Heinz Co. Ltd, Architects: J. Douglass Matthews and Partners. Vauxhall Motors Ltd Ellesmere Port factory, by Howard Fairburn and Vauxhall Engineering Dept. Factory extension for Cooks Corrugated Cases Ltd, Hatfield, Structural Engineers: A. J. Jullien Ltd, Main Contractors: L. Davis (Holloway) Ltd.

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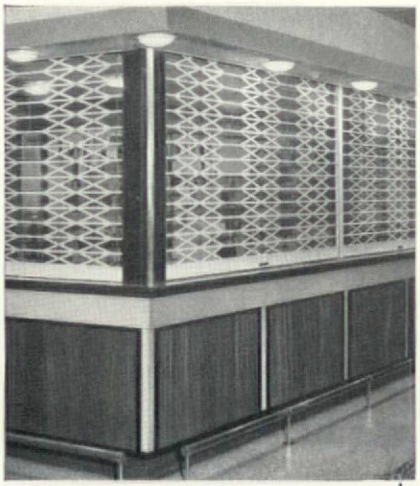

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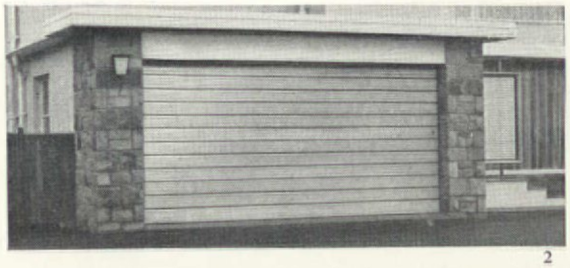

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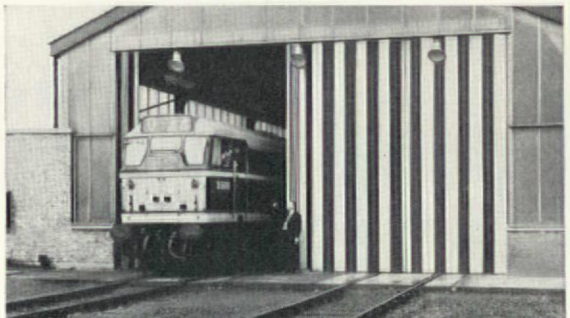

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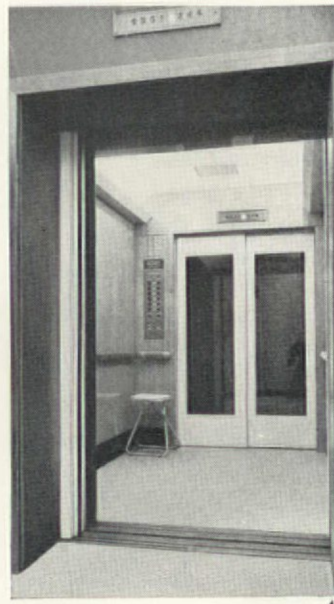

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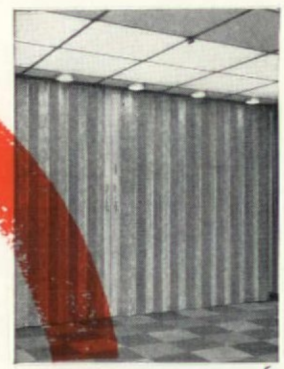

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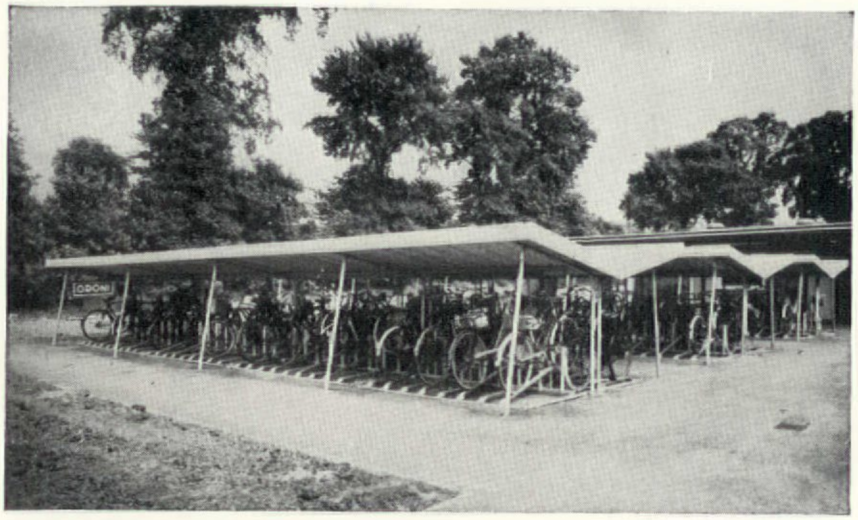

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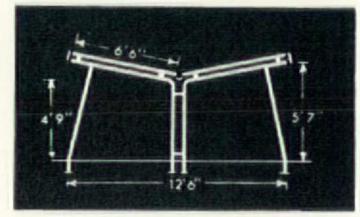

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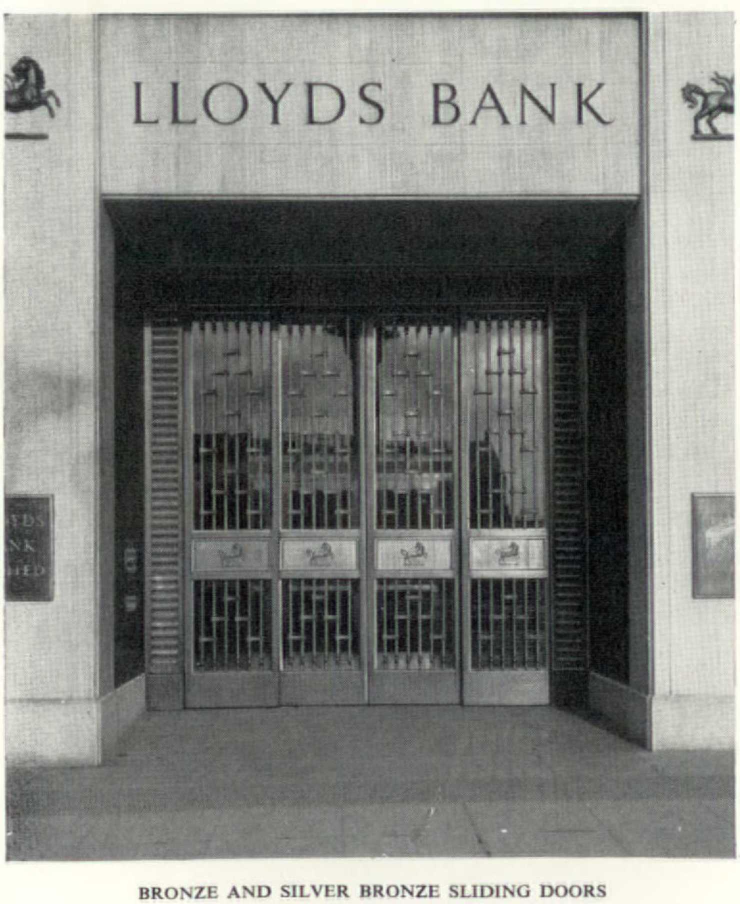

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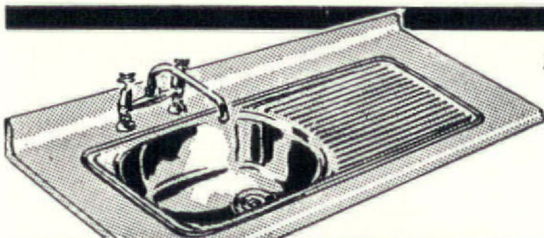

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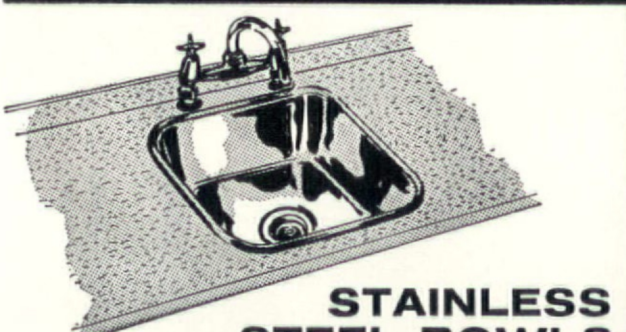

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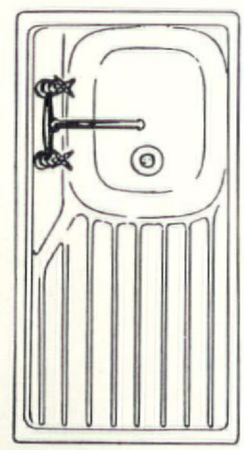

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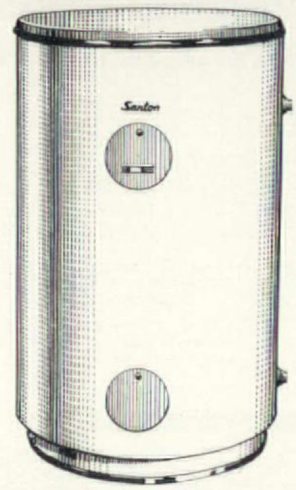

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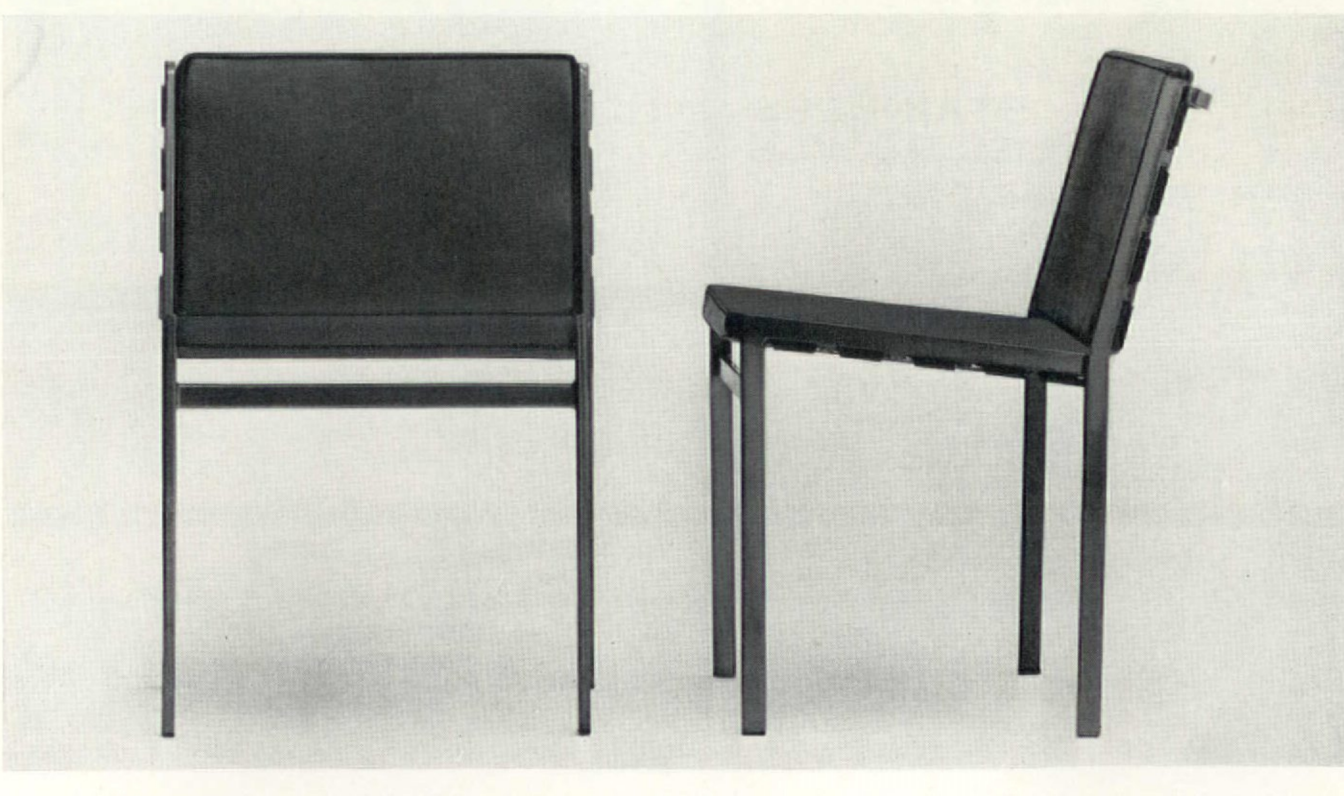

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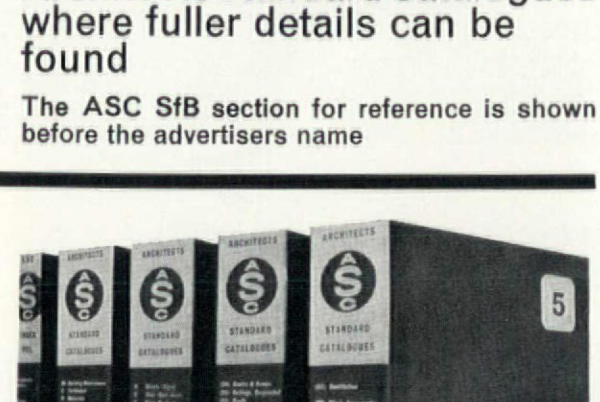

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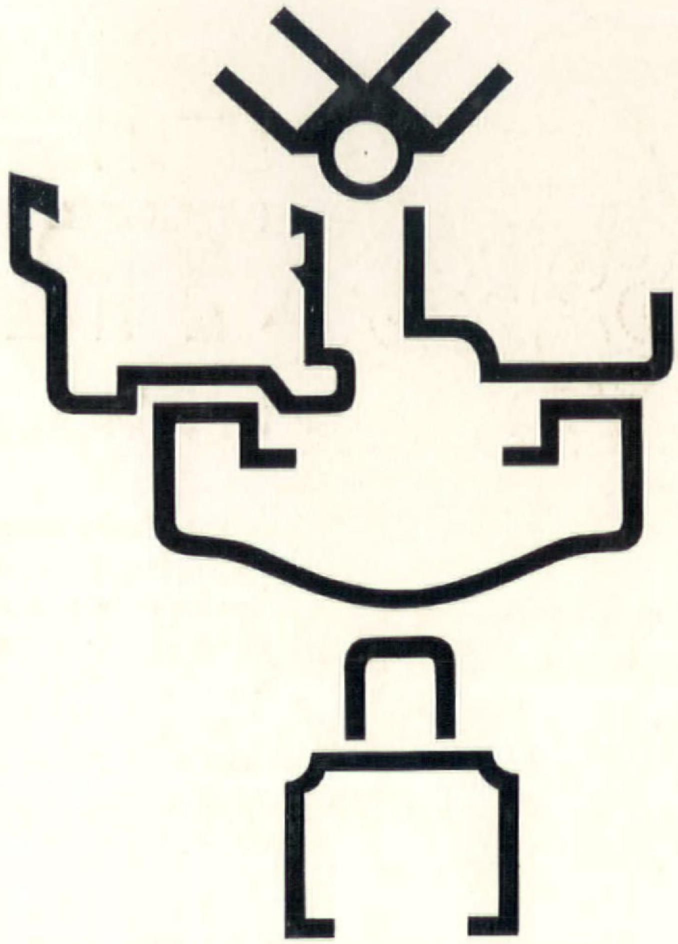

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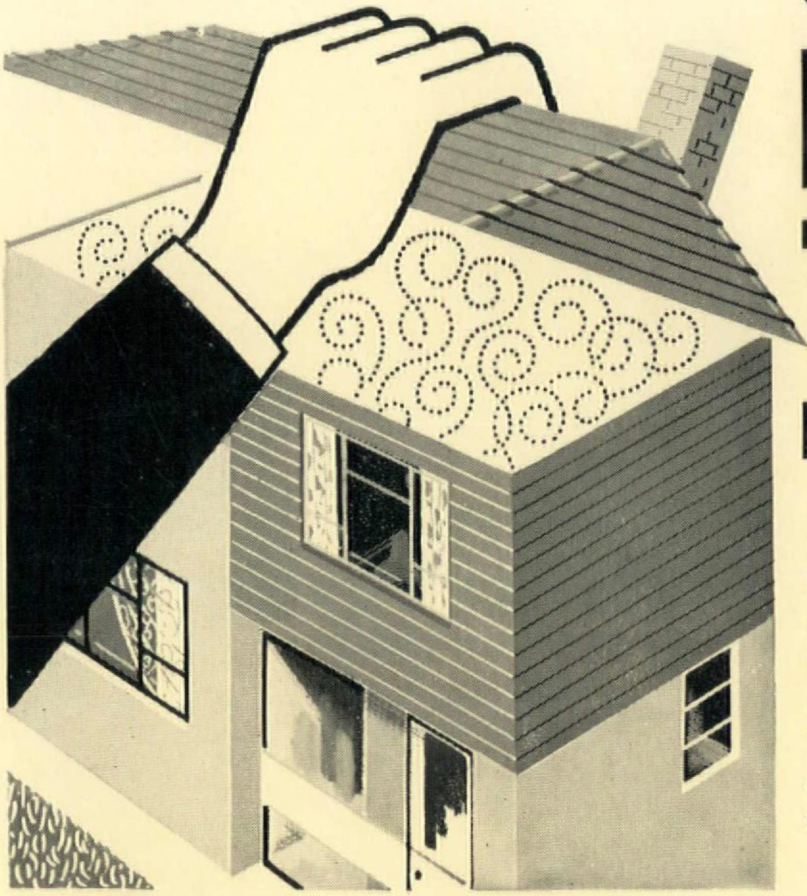

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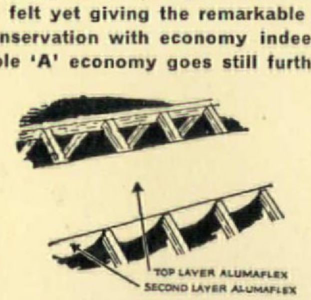

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