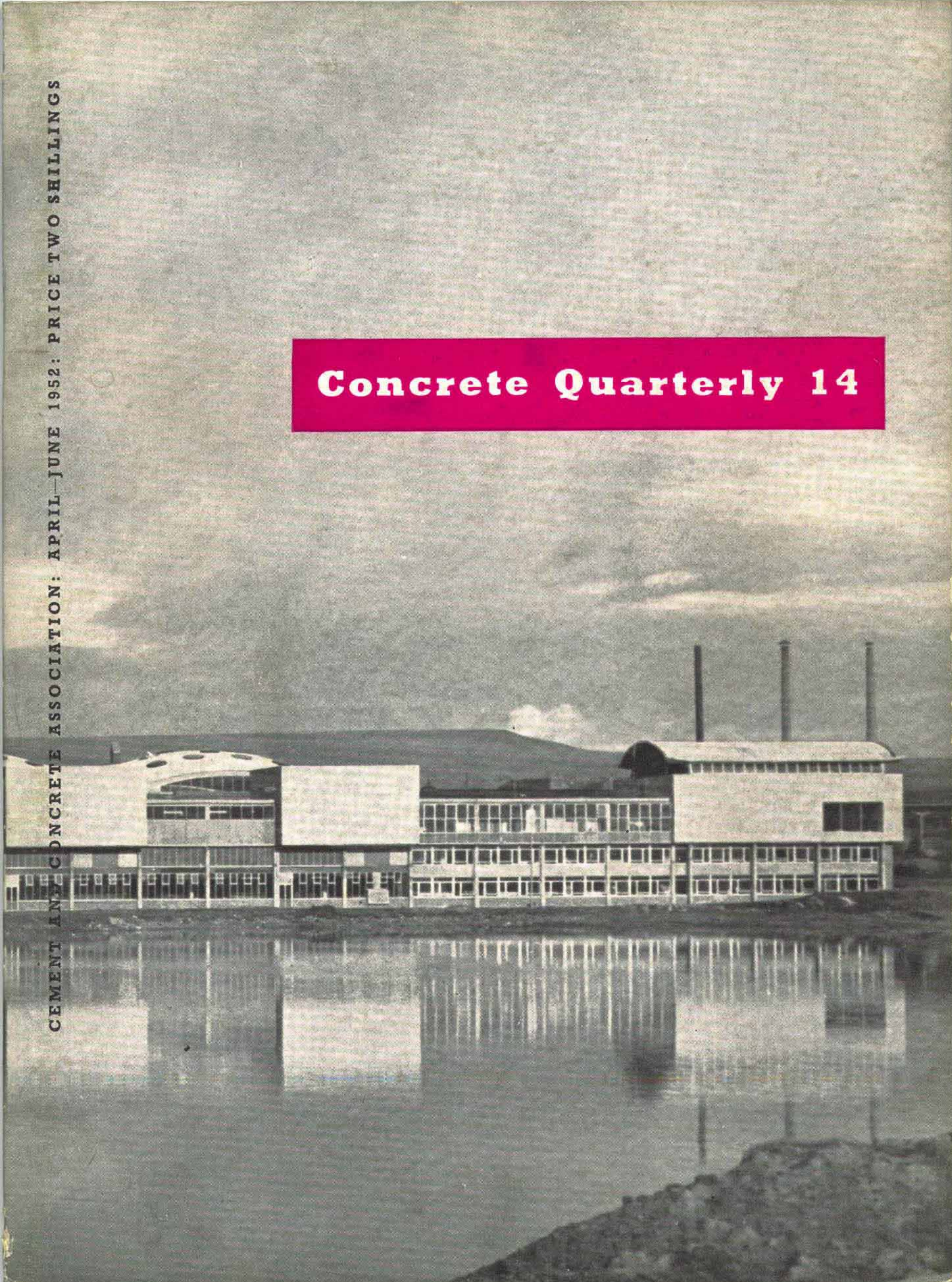
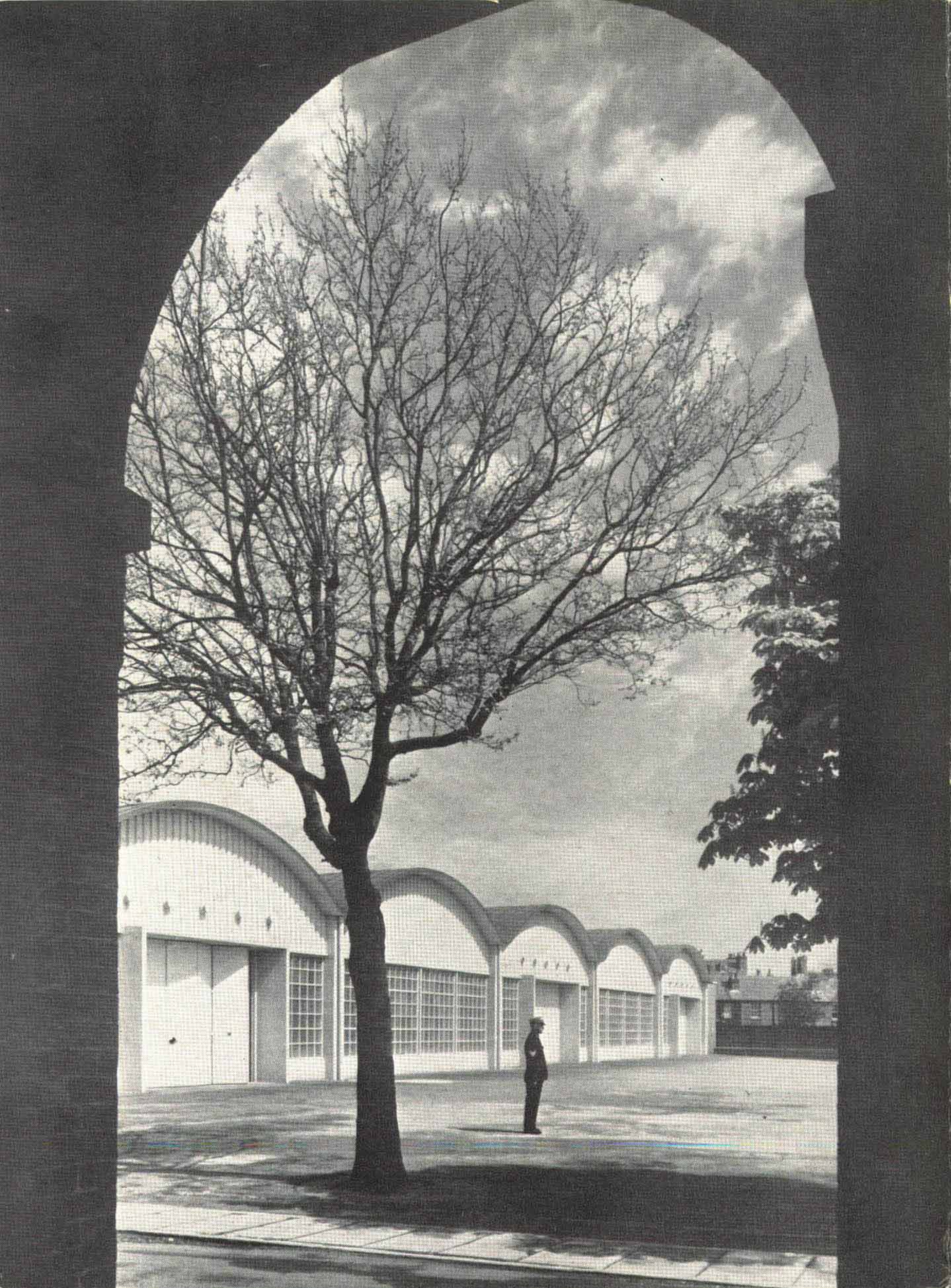
Concrete Quarterly 14

CEMENT AND CONCRETE ASSOCIATION: APRIL—JUNE 1952: PRICE TWO SHILLINGS





Concrete Quarterly 14

CEMENT AND CONCRETE ASSOCIATION: 52 GROSVENOR GARDENS SW1

CONTENTS FOR APRIL-JUNE 1952

THE FIVE HUNDRED-ODD shell roofed buildings in existence in this country, nearly all of them built in the last half-dozen years, is evidence of the growing appreciation of the possibilities of concrete shell roof construction. It is a form which is by no means new, even in this country and certainly not on the Continent, but it has only comparatively recently become popularized. In its early days shell construction was something of a mystery, the prerogative of the great engineering pioneers and the monumental structure. It was shell roofing on a grand scale—the scale of the Market Hall at Leipzig, built by Dischinger in 1929. But since then engineers in many countries have been investigating and simplifying the mathematics of shell construction, while young architects in search of new forms of expression have had a vision of the quite new things they could do with this new tool the engineers had given them, and have found in it a fresh source of architectural inspiration. Designers, at the same time, have been simplifying the formwork for shell construction, and as the buildings went up, industrialists have recognized that here was a way of obtaining what each of them wants—a clear uninterrupted floor space.

So shell design has started to come into its own. Not that its possibilities have been by any means fully exploited. Until now engineers and architects have never enjoyed a full exchange of views on shell construction practice and lines of development in this country and abroad. It was to fill this need that the Symposium on Concrete Shell Roof Construction was convened for this summer. For three days architects and engineers and construction specialists are pooling their ideas and the results of their research.

And, for once, architect will not only talk to architect and engineer to engineer, but each will have the opportunity of sharing his views with the other. In shell construction both architects and engineers are finding problems and solutions that widen the range of both. It offers them, as few recent architectural developments have done, an opportunity of close co-operation in which each uses to the full all that the other has to give.

In the past architects have sometimes been slow to grasp the potentialities of the great engineering discoveries of their time. That is far from being the case to-day, when on every side there is a seeking for a new means of expression, which at the same time is a natural growth—which fills a need and is not just new for newness' sake.

And among many engineers the habit has died hard of looking on 'architectural' as a word that means a rather useless decoration. Shell concrete proves that construction and architecture are really one and indivisible, and there is hardly an example in this 'shell' *Concrete Quarterly* that does not point the moral.

FRONTISPIECE: *The new drill hall at the Royal Marines' Depot, Deal, seen through the arcades of the old barracks buildings.* *See page 48.*

COVER: *The rubber factory at Brynmawr.* *See page 26.*

CONCRETE QUARTERLY 13: ERRATA

The prestressed concrete bridge in University Park, Oxford, which appeared as the frontispiece in "Concrete Quarterly" 13, was incorrectly described as being tensioned on the Magnel-Blaton system. The Freyssinet system of prestressing was in fact the method used in the construction of this bridge.

"*Fire hose must be dried*": It is regretted that the name of the County Architect of Essex, who was mentioned in connexion with the prestressed concrete fire hose towers described on page 8 was incorrectly given as H. J. Berry, M.I.C.E., M.I.Mun.E. The County Architect is, of course, H. Conolly, F.R.I.B.A. Mr. Berry is County Surveyor.

The factories at CRAWLEY NEW TOWN

Bright, attractive and set in pleasant grass-bordered roads, they are an enticement to small industries

UNTIL A NEW destiny was decreed for it, Crawley, midway between London and Brighton, was just a small country town in a farming district. Some 4,000 people lived in Crawley when it was chosen in 1946 to become one of the New Towns within the orbit of London. Another 5,000 lived at nearby Three Bridges and in scattered and ribbon housing developed round about—a total population for the area of some 9,000 people. As a New Town its population is to be increased to fifty or sixty thousand ; industries are coming from London to make the town a place complete in itself, and with them come the industrial workers, from directors to factory hands, to make their homes there.

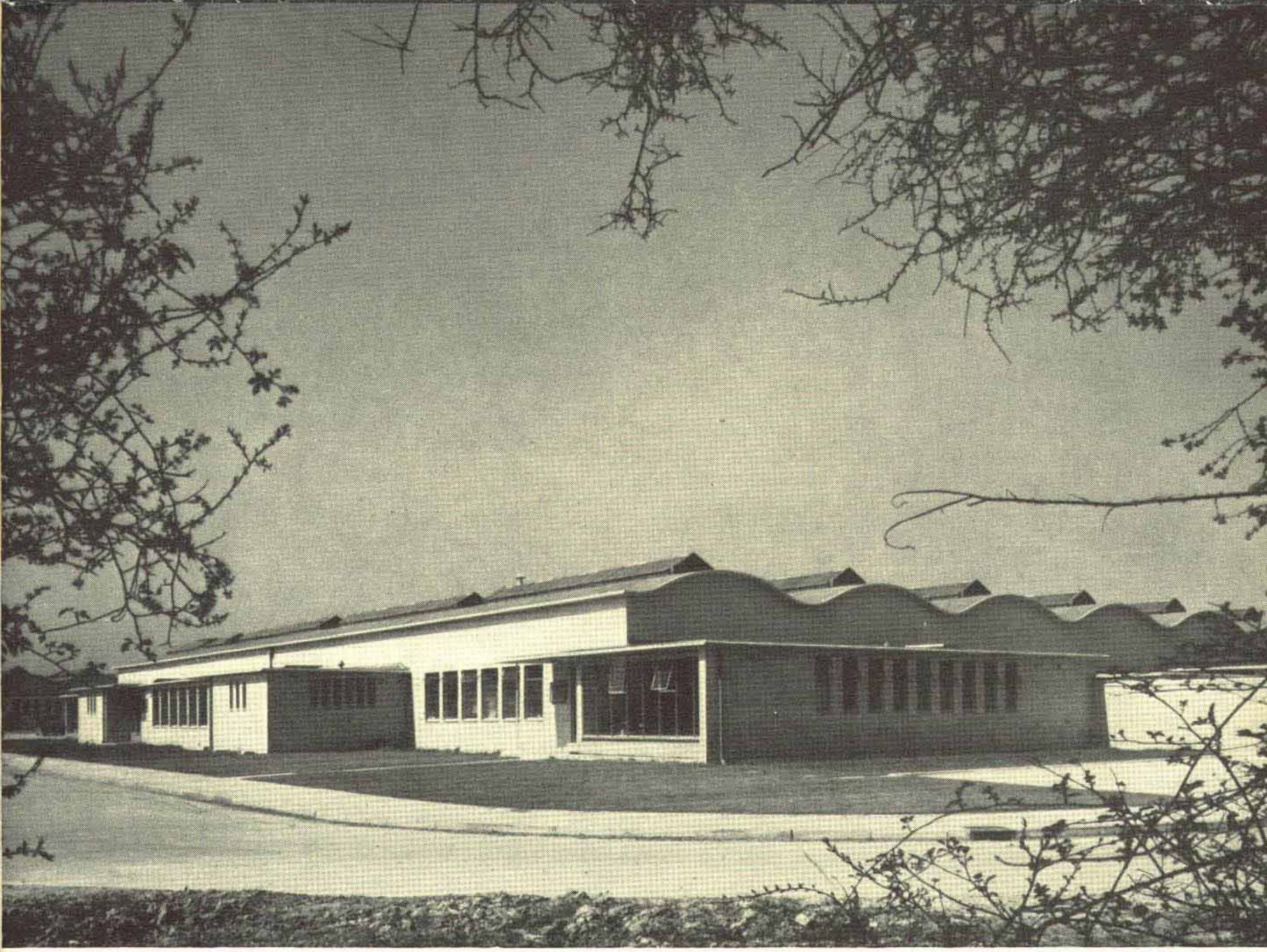
Crawley's activities have always centred on its wide and lovely High Street where timbered houses lean together on either side and the sign of the "George" inn bridges the road. Unlike some development schemes, where the new town is divorced from the old, at Crawley the High Street is to form the kernel of the New Town. For some time to come it will remain the chief shopping and entertainment centre, while houses and factories take precedence in the building scheme. These are progressing steadily. Streets and avenues of houses are already lived in, while the industrial district, away to the north-east on the London side, has already taken its very pleasant shape.

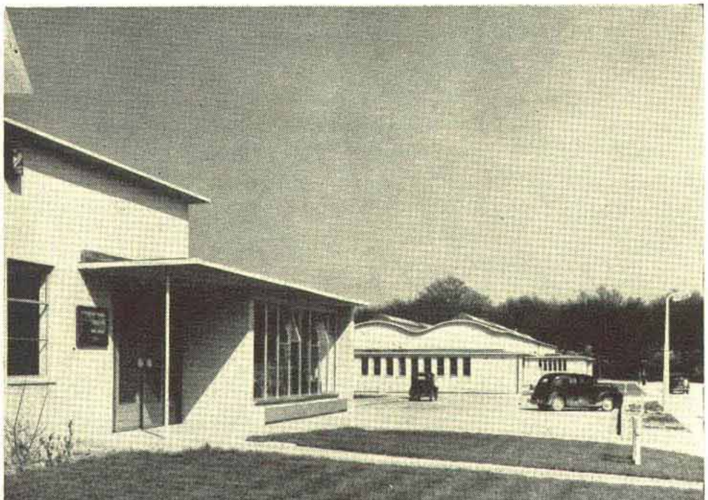
If all industrial districts could resemble that of Crawley New Town, they would be very much happier places, and industry would more than retrieve its reputation for bringing ugliness in its wake. It could instead earn itself a new reputation, for adding something of real charm to a growing town.

Crawley industrial district is—yes—charming. The industries are, of course, all light, but they are immensely varied — plastics, laboratory equipment, scientific instruments, vitamin foods, confectionery, hoists and building machinery, dairy equipment, cleaning fluid, printing ink—and with the exception of a few large concerns who have built their own works, factories built by the Corporation to one standard design have admirably suited every one.

When the district was planned it was correctly assumed that many of the firms who would move from London to Crawley would be small or smallish concerns who would not be likely to undertake the construction of a factory themselves—or at least not of such a factory as the Crawley Development Corporation envisaged for its new town. A dual scheme was therefore evolved : the district as a whole was planned and parcelled out and, keeping within the outline of the "key" plan, individual firms who wished to employ their own designers and build their own factories were at liberty to do so. For the rest the Corporation has designed groups of standard factories suitable for letting to smaller manufacturers, some of whom might not require more than about 5,000 sq. ft. of workshop area.

For these factories to be let at a rent which would be both economic for the Corporation and attractive to the client, it was necessary for the cost to be reduced to a minimum. But standards of appearance, convenience and permanence must not suffer ; they had, in fact, to be so high that the Corporation-designed factories would be a challenge and an example to the private builder. The cost aimed at was based on that of the simplest possible structure—a light steel-framed building with an asbestos cement roof. Before the method of construction was decided on, some forty different types of design were examined and analyzed in detail. Gradually the advantages of shell roof construction for these buildings became apparent and held their own against all the other possibilities. And so shell construction was adopted. It was found that used in the most structurally efficient way, as





Above and left: The pleasant little factories at Crawley New Town, attractive in outline, light and well ventilated with lantern lights in the shell concrete of the roof, and surrounded on three sides by the flat-roofed office block. Well-kept lawns stretch between the buildings and the concrete road.

here, the shell roofed factories were no more costly than the light steel-framed, asbestos cement roofed structure used as a 'control.'

These factories, built in blocks of not more than 23,000 sq. ft. floor area, line pleasant open concrete roads where belts of trees are preserved and trim grass verges border the pavements. It is one of these roads, incidentally, that is England's first prestressed concrete road, laid experimentally in 1950.

The design of these small factories is charming, their uniformity a pleasing discipline without monotony. The neatness, the small scale, the graceful flow of the undulating shell roofs contrasting with the glass-fronted, flat-roofed lower-level projection that houses offices and cloakrooms, together make up a picture that is balanced, harmonious and attractive.

Each factory block is made up of two, three or four—generally four—bays, consisting of six barrels, each 40 ft. long by 20 ft. wide. Each bay can be completely self-contained, having its own office and cloakroom accommodation and its own entrance, and can thus be divided off by a party wall to become the complete factory for one tenant, clear from end to end. In other cases one tenant will lease the whole block, in others again a four-bay block will be divided equally between two firms.

The 40 ft. by 20 ft. grid is maintained throughout all the blocks. The 2½ in. thick concrete barrels are carried on slim columns that contain the down-pipes. Stiffening beams occur between bays, at the 40 ft. intervals, coinciding with the party wall when the building is divided. To dispense with the extra cost of lintels, end stiffening beams on the outside of the building are dropped a little lower than the valleys to form the window and door heads.

Service ducts and fittings are cast into the concrete of the structure itself and exposed service runs are fixed to concrete stiffener beams. The junction of valley beam and stiffener beam has been so detailed that the valley soffit is 8 in. above the stiffener soffit, thus providing an uninterrupted run for services around the perimeter of each standard bay. This enables ring mains to be provided round each bay and fixing can commence as soon as the shell of the building is complete, thus avoiding the necessity for waiting for other trades before services are installed. Fixtures for lifting tackle, cranes and other overhead equipment are provided at frequent intervals, so as to be adaptable to the varying needs of widely different processes. These fittings are standard; individual needs are also catered for when the factories are taken over, special equipment being built in as required by the manufacturer.

Inside, the factories are all flooded with clear, shadowless light. Daylight, coming from roof-lights that run practically the length of each barrel, is reflected from every part of the curving roof and inside there is an even daylight factor of 20 per cent. The finish of the barrels, both internally and externally, has undergone some changes since the first buildings were erected. Originally they were cast on fibreboard sheeting which provided permanent insulation, and covered on the outside with roofing felt. The sheeting was finished internally with cement paint. Experience showed that this could be improved on and roofs are now cast on metal formwork, insulation being provided by a cork screed on the outside, which is in turn covered with the roofing felt, while internally cream-coloured anti-condensation cement paint is applied direct to the concrete.

In the layout of the factories also, experience has enabled improvements to be made. Originally factories had access from both front and back, the yard at the back giving on to a service road and all the office and cloakroom space being concentrated at the front. It was found, however, that in some cases the proportion of office workers to factory employees was much higher than was anticipated, and furthermore that it would be an advantage to have the possibility of extension to the rear. Consequently the most recently built factories have office and cloakroom blocks surrounding the factory section on three sides, and all entrances are being kept to the front, a 'green belt' being left at the rear of the factory for eventual expansion if and when necessary.

As they are now evolved, after the experience of building some half-dozen blocks, these small factories are as adaptable, as practical and as economical as any design could be. Their cost is low, and their appearance is attractive. So successful are they, in fact, that some of the large manufacturers moving into Crawley have decided on seeing them to adopt shell construction for their own privately built works.

The factories were designed by the corporation's Chief Architect, A. G. Sheppard Fidler, M.A., B.Arch., F.R.I.B.A., A.M.T.P.I., with Barrel Vault Roofs (Designs) Limited as reinforced concrete consultants. G. W. Jepson, Dip.Arch., A.R.I.B.A., is architect in charge and the general contractors are Holloway Brothers (London) Limited.

They are gone, the leisurely days of hansom cabs and horse buses, but at **BULL YARD, PECKHAM** *the one-time horse-bus depot still houses London's buses—in a vast new shell-roofed garage*

THERE WAS an old lady once sat beside me in a London bus. Not the sort of old lady you would notice. Small and brown and dreadfully shabby, she huddled in her corner, fumbling a little with an old cloth bag.

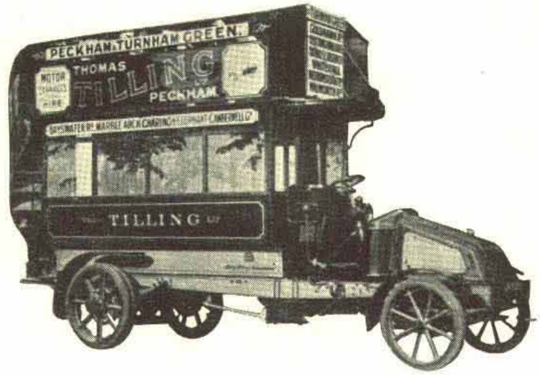
Then she spoke. There was a hold-up and on the kerb, waiting his chance to cross the road, we had time to watch a man, silk hatted, in full morning dress. A youngish man with a flower in his buttonhole. "You don't often see that nowadays," she said, and her voice, old and rasping, was the voice of a gentlewoman none the less. And then she went on to talk as we jerked up Piccadilly, stopping and starting, of the Piccadilly of fifty, sixty years ago, when she was a young woman, a young girl. She was eighty now. Remembering, and seeing it as she talked, you saw it too as you listened. "Piccadilly was a very different place in those days," she said, and you saw the polished carriages, the high-stepping horses, the leisured gentlemen pausing for a chat on the steps of their club. "There's the Naval and Military Club—the old 'In and out.'" She pointed it out as we passed its doors. "My husband used to belong to the 'In and Out.' But it's not what it was —only regular officers could be members in the old days, but it's different now." "People had leisure in those days," she went on, "there was none of this hurrying about—none of these crowds. You never saw ladies walking, either— not here, in Piccadilly—only 'females.'" And so you saw the even more leisured ladies, feather boa and feathered hat, leaning graciously from a carriage to exchange an invitation to tea, perhaps, with the dashing gentlemen at the kerbside.

Then as we approached the Circus she talked of the traffic in Piccadilly. Of the four-in-hands, and then the horse-buses, chocolate, blue, scarlet, and the strong, patient horses—two horses to each bus with a third waiting at the foot of the hills to be harnessed in to give the extra pull.

Nostalgically, her old voice conjured up a picture of a world gone for ever, for better or worse, leisured security, four-in-hands and horse-buses alike. It is an odd fact that horse-buses, though they were in operation as early as 1847, did not reach their heyday until they were, in fact, doomed. The rattling horse-bus, with its curtained windows, its high-perched driver, its bowler-hatted conductor, organized to cover efficiently all the main routes of London and giving you a penny ride from Westminster to the Old Kent Road, clopped gaily through the Edwardian city to a knell already being sounded by the horns of the encroaching motor-cars.

Down in Peckham, behind the Red Bull Inn, was the mews where Thomas Tillings, largest of the horse-bus companies, stabled their horses and housed their chocolate and cream buses— leasing the premises until 1911, when they bought the whole mews. And by this time Tillings were already changing over from horses to those new-fangled motors.

But before Tillings finally switched to motor buses there had been, about 1904, an intermediate stage—the petrol-electric bus, the first of which was built here in Bull Yard. Apparently the old horse drivers, when set to motor driving, found the clutch an insurmountable difficulty, so this vehicle was evolved to eliminate it. A petrol engine worked a generator which



Two reminders of the old Bull Yard, before the days of motor buses. Left : a horse bus, that might once have been housed in the Red Bull Mews ; Right : the petrol-electric bus, the first of which was built at Bull Yard.

powered an electric motor which in its turn drove the bus. The petrol-electric bus had a life of some years before it was finally superseded by the genuine motor buses, and all this time the Bull Yard premises were growing. In 1919, 1923, 1925, more property was added to the site, and part of it was used for the maintenance and building of buses. In the thirties the London Passenger Transport Board took over the premises, and then came the war and the whole garage was destroyed.

Now Bull Yard is rebuilt. Still as a bus garage—one of the most modern in the country, one of the best equipped and embodying the most appropriate method of construction for such a building—shell concrete.

Bull Yard bus garage, facing Peckham High Street, covers $2\frac{3}{4}$ acres and besides the garage itself, includes maintenance shops, administrative offices, a staff canteen and recreation rooms and the Transport Executive's South East Divisional Medical Centre.

The garage has parking space for 150 buses and will provide maintenance and repairs for 200 more from the subsidiary garage at New Cross which is now being constructed. The main parking garage covers an area of 240 ft. by 220 ft. and is roofed with twelve reinforced concrete shells in two bays of six shells each. Both series of shells are carried centrally on a massive reinforced concrete beam which is supported on only two columns, providing an almost uninterrupted floor area of 52,000 sq. ft. Individual shells are 40 ft. wide and span a length of 120 ft. They are of 3 in. thick concrete with edge beams 4 ft. deep, and are pierced by circular ventilators and dome lights in the apex, as well as by square roof lights in the slopes. Externally the shells are insulated with a Vermiculite screed covered with bituminous felt; internally they are finished with 'Snowcem.'

The 240 ft. long central beam which carries all twelve shells is $12\frac{1}{2}$ ft. deep, and transfers a weight of 565 tons to each of its two supporting columns. These columns are circular in section, being formed with permanent formwork of precast concrete piping. Each is carried on a group of in situ reinforced concrete piles, 18 in. in diameter and 34 ft. long. The beam was constructed in two halves, each $14\frac{1}{2}$ in. wide, with a one-inch expansion joint between them.

The maintenance section, which is separated from the garage by sliding doors, covers approximately 15,000 sq. ft. and is roofed with northlight shells.

Buses are washed, vacuum-cleaned and fuelled daily in the large parking hall. They drive in from the back entrance, in Hanover Park, to the vacuum-cleaning plant where powerful suction pipes at two levels are passed through the windows to clean out the interior. They then move on to the washing apparatus—an 'Essex' cleaning plant—and are stopped, when in exactly the right position, by a signal on the windscreen. A frame, equipped with sprays and revolving brushes, is then lowered around the bus, which is attacked on all sides and washed from top to bottom, and up from bottom to top. When the frame is again clear, an automatic light gives the signal to the driver who can then take his bus straight on and out by the Peckham High Street entrance, or into the parking area, as required.

Besides the daily washing, 350 buses are inspected and overhauled on a rota system that

Part of the parking area at the new Bull Yard garage. Across the centre is the beam which carries both sets of shells and which is itself carried on two reinforced concrete columns, one of which is seen on the left.

gives each one a one-hour examination every three weeks, a four-hour treatment every nine weeks, and a full day's overhaul every eighteen weeks.

This work is carried out in the adjoining maintenance section, where inspection pits are of the newest design and equipped with every device that will make work easy and efficient. Fluorescent lights in recesses in the pit sides protected by toughened glass, give shadowless light throughout; recesses are provided for tools; ledges will take a standing board that will raise a short man to a convenient height. Compressed air, oil and grease are fed to the pits, and arrangements made to convey exhaust fumes direct to the outer air, so that engines can be run without contaminating the atmosphere. A warm, even temperature is maintained in all weathers by overhead heating apparatus and the northlight shell roof provides ample daylight to the main floor of the section.

Offices, canteen and medical department are housed in the two-storey, flat-roofed building facing the road—a reinforced concrete framed building, brick finished, which bridges the 69 ft. wide exit from which the scarlet buses fan out over London.

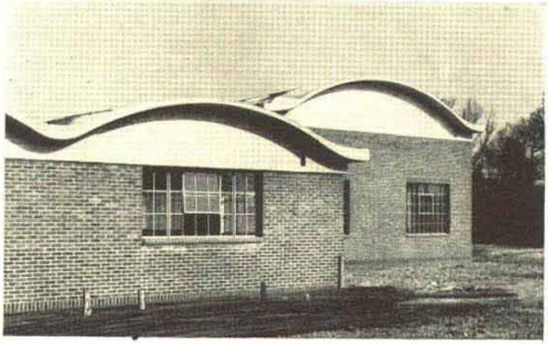
Plans for the new Bull Yard garage were prepared by Wallis Gilbert and Partners, in association with T. R. Bilbow, F.R.I.B.A., Architect to London Transport. Consulting engineers were John Liversedge and Associates. Contractors for the reinforced concrete work were Richard Costain Limited and John Jarvis and Sons Limited. The whole of the work was carried out under the general direction of P. Croom-Johnson, C.B.E., Chief Engineer to the London Transport Executive.

Fine concrete gives outstanding quality to the

SHELL ROOFS AT COLNE VALLEY SEWAGE WORKS

A GREAT DEAL of fine work—and fine concrete—has gone into the construction of the Colne Valley Sewage Works at Rickmansworth. Nowhere, though, is the quality of the workmanship seen to better advantage than in one comparatively small-scale section, the maintenance buildings, where it is allied to the lovely proportions of a well-designed shell roof.

These buildings form four sides of a rectangle—workshops, offices and stores enclosing three sides and a separate garage completing the fourth. A large continuous shell-roofed building runs the full length of the south side; the east end is closed by a storehouse roofed with a series of four narrower shells, the last of which is extended to form the north side of the quadrangle. The two-barrel garage stands at the western end. The enclosed courtyard is paved with concrete, with a small oil store building and petrol pumps in the centre.

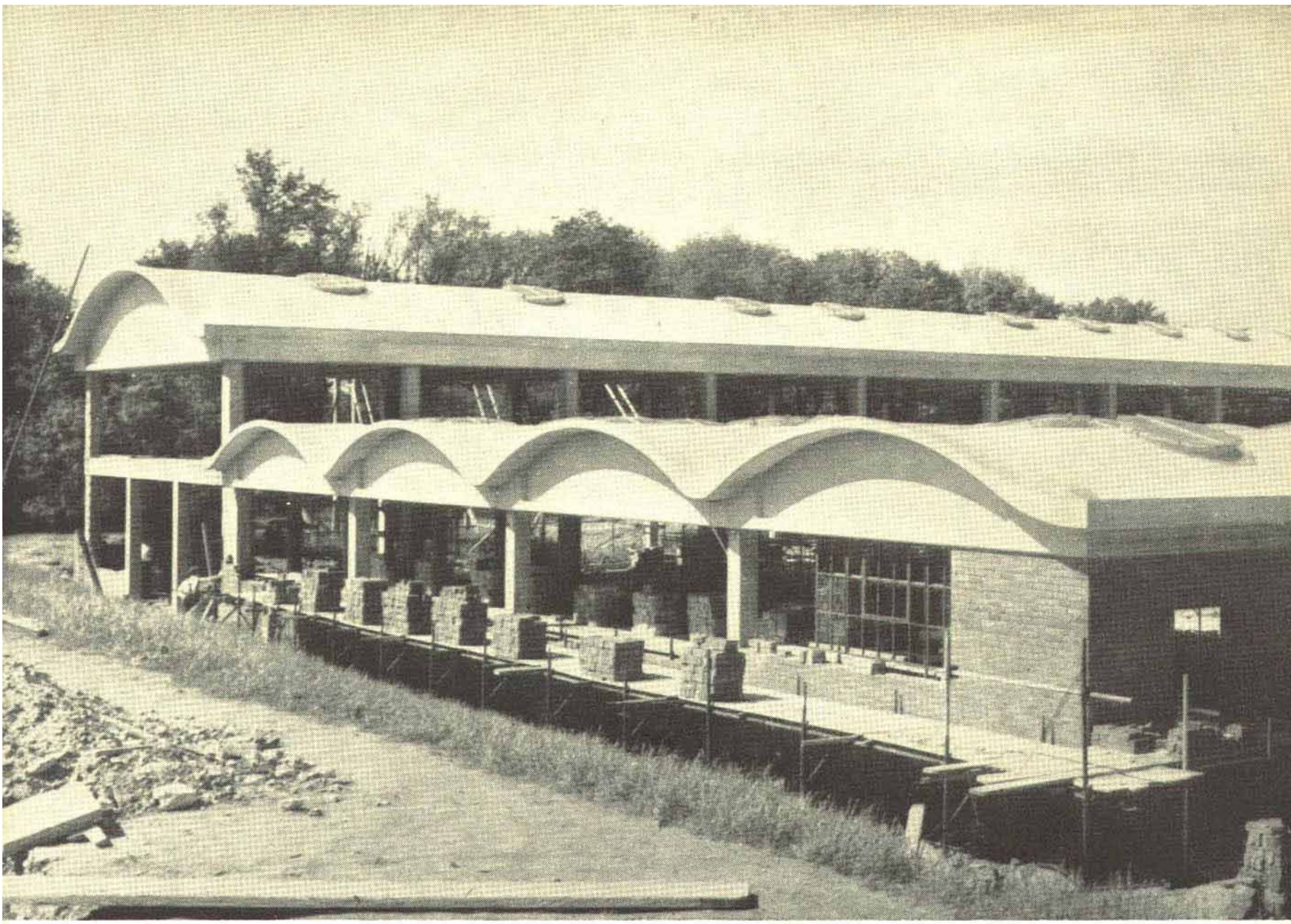


Gable ends of the garage and main building; the fine workmanship is apparent in the sharp, clean lines of these structures.

The main building, larger and higher than the others, is 199 ft. 6 in. long and 42 ft. wide, and is 27 ft. high at the crown, rising from 19 ft. 6 in. at the edge beams. In it are installed machinery repair shops of different kinds, and a crane rail beam runs down its either side supported on columns at 15 ft. 9 in. centres. These columns continue up to the roof, which is stiffened by 24 in. deep edge beams and two transverse diaphragms spaced 78 ft. 9 in. apart.

The storehouse at the east end of the quadrangle is lower, its shells rising only to a height of 14 ft. 3 in. at the crown from 10 ft. at the springing. This building provides clear floor space covering 67 ft. 9 in. by 40 ft.; each barrel is 45 ft. long and 22 ft. 6 in. in chord width. Valleys are rounded externally to the graceful curve so characteristic of concrete shell construction, and the necessary thickening of the concrete at the valleys and edges—from 2½ inches thickness at the crown—is exactly what not only engineering but the eye requires for a completely satisfying outline. The fourth of these barrels roofs the building which forms the north side of the quadrangle. A little shorter than the main repair shop—it is 171 ft. long—it is divided by partition walls into a number of different compartments: joiners' shop, paint shop, first aid room, electrical equipment room, changing rooms and lavatories and offices.

This group of buildings is utterly unpretentious, but exactly right and one's immediate feeling is of pleasure in seeing a material beautifully used. Their lines are clean and sharp—no fumbling, no blurred edges.



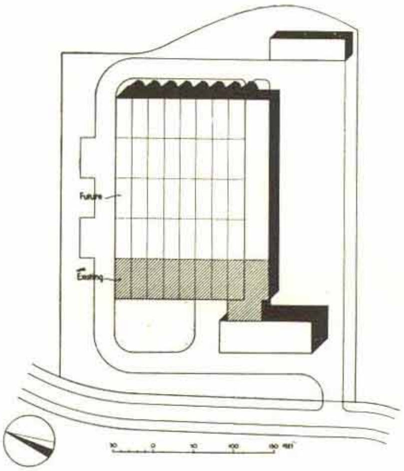
The maintenance buildings under construction. In the background is the main repair shop, in front the storeroom, with the general building on the right.

And the concrete is here a lovely material in its own right. Fine in texture, even and light in colour, it is a shining witness to the value of careful control in the production of high quality work. Mixing and placing were treated as craftsman's work; a ganger was in charge of the placing and a leading hand was responsible for the mixer. The mix gave a 1½ in. slump and was tested for consistency after every fourth mixing. Vibration was not used. The concrete was compacted by hand throughout and every detail was treated with meticulous care: the arrises are knife-sharp, and the dense, close texture unvarying. The finished concrete was rubbed over with carborundum stone and has everywhere been left exposed.

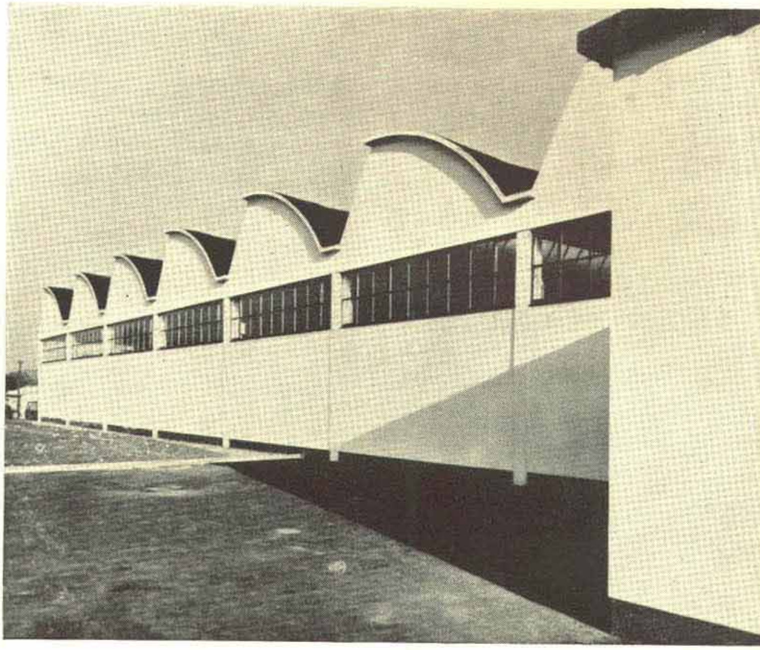
The concrete of both shells and columns was cast against timber forms: 6 in. wide boards tacked to 2 in. by 2 in. bearers bent to shape for about 40 per cent. of the work and, owing to difficulties in getting supplies of these 6 in. by 1¼ in. boards a hardboard soffit tacked to the same timbers spaced slightly apart for the remainder. The underside of the shell was rubbed down with carborundum and finished with white 'Snowcem' for additional light. This is the only surface addition to concrete that is everywhere unconcealed.

The brickwork used as infilling for the walls is also admirably regular and pleasant in colour—the warm, plum-toned graduations of multi-coloured rustics.

The consulting engineers for the whole of the Colne Valley scheme—Sandford Fawcett and Partners—were responsible for the overall design of the maintenance buildings, which were completed in June 1951. Twisteel Reinforcement Limited supplied the steel and construction details for the shell roofs. Contractors were W. & C. French Limited.



Above: Site plan. The shaded portion is the part already constructed. Right: One end of the factory.



Historic . . . and four years old

The pleasant little textile factory at Congleton is one of the earliest of England's northlight shell buildings

THE SMALL FACTORY at Congleton, Cheshire, designed by Rudolf Frankel, F.R.I.B.A., for Sotex, manufacturers of knitted clothing, is in fact only one-fifth of the entire building planned. The existing factory consists of eight shell-roofed bays, covering a total area of 160 ft. by 54 ft. and a flat-roofed extension at the south end which houses first-aid room and lavatories. The whole factory when completed will comprise 40 similar bays, and the flat-roofed section will be continued the length of one side; to accommodate cloakrooms and wide loading bays. At the south-west end, linked to the main building by a hallway (now the main entrance) will be a two-storey canteen and office block.

The section built in 1948 must be one of the earliest examples of northlight shell construction in England. And so quickly do we become accustomed to new forms that the novelty of only four years ago is simply another attractive building to-day.

Individual barrels, which are carried on reinforced concrete colums, have a span of 50 ft. and a width of 20 ft. with a radius of 17 ft. 6 ins. Externally they are covered with bituminous felt, and inside are lined with insulation board painted white.

The 11-inch cavity walls are brick, rendered externally and painted white. A band of window, interrupted only by the columns, runs the entire length of the building on both sides, its top on a line with the springing of the shells.

Dark blue engineering brick makes a plinth round the base of the building, as well as entrance steps and paving and the blue theme is echoed in the paintwork of window frames, doors and gutters.

Engineers for the design of the shell roofs were Barrel Vault Roofs (Designs) Limited. Main contractors were R. John Addison Limited with F. Bradford and Company Limited as special contractors for the shell roofs.

60 DOMES *of prestressed concrete*

roof a Le Havre warehouse for storing cotton

NUMBER ONE WAREHOUSE on the Quai de la Garonne at Le Havre was built before the war to deal exclusively with the needs of the cotton trade. Cotton is a seasonal import. Purchases are made at the end of the year, immediately after the harvest, and the bales of raw cotton are shipped at once, so that the entire year's cotton imports arrive in port within a very short space of time. But the rate of distribution has clearly very little relation to the rate of unloading, so a considerable storage problem arises at the port of arrival. Hence the chief requirement in a cotton warehouse is size ; second is clear space for ease of handling the bales ; third, of course, is fire resistance—cotton is not only bulky but highly inflammable.

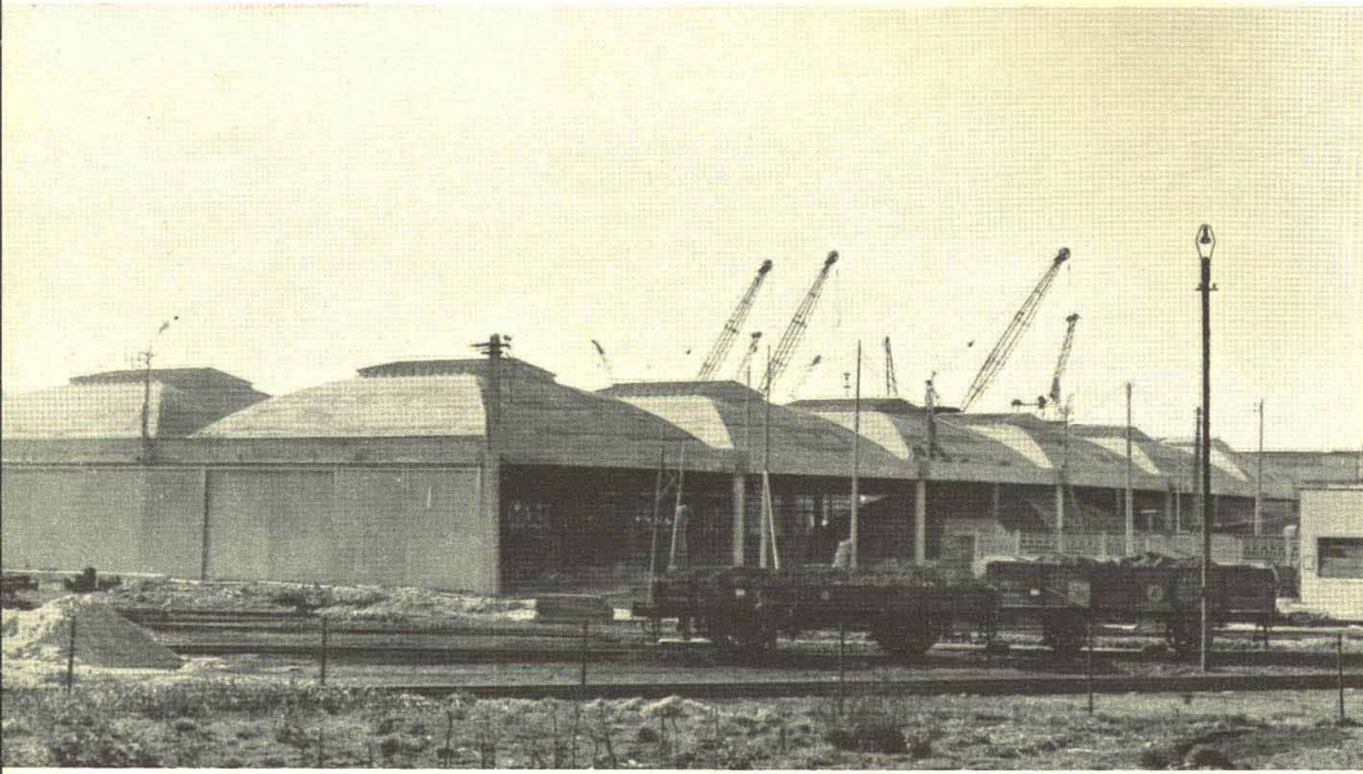
In 1939 the cotton warehouse at Le Havre docks was 2,460 ft. long and 370 ft. wide. The storage space it provided was ample, but from the point of view of clear space the construction was not ideal. During the war, the fire and high-explosive bombs that demolished practically the whole of the dock area of Le Havre seriously damaged two-thirds of this huge warehouse and completely destroyed the remainder.

As soon as possible—in 1946 and 1947—repairs were put in hand and the damaged part of the building, some 1,800 ft. long, was returned to use ; the remaining 660 ft., of which nothing but rubble remained, could not be re-built at the time because of shortage of materials. Eventually, in 1949, plans for reconstruction were made. Competitive tenders were called for and the designers, untrammelled by any existing structure, were able to make use of all the new developments that had grown up since the war. The successful design, submitted by the Société d'Ouvrages d'Art et Travaux, embodied the then entirely novel conception of shell roof construction allied with prestressing.

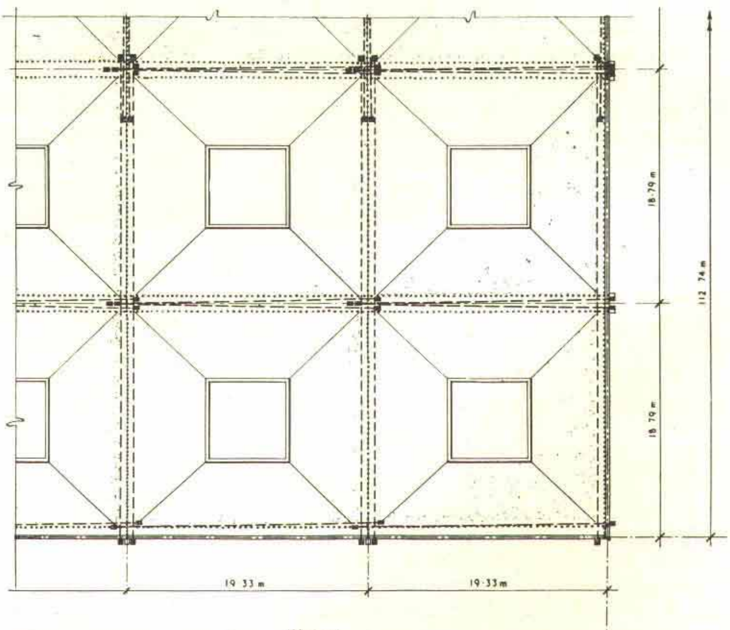
The area, covering a total of some 243,250 sq. ft., is roofed with sixty 'biretta-shaped' shell concrete domes, square of base, their four curved sides converging to the crown where they are pierced with a roof light. Each dome, in fact, a groined roof.

The main factor leading to the choice of thin shell roof construction (apart from cost) was, of course, its provision of clear open space, with a minimum of supports. The unusual shape of the shells was the outcome of a search for maximum fire resistance.

These domes, in which all sides are approximately equal (they measure 63 ft. by 61 ft. 6 in.) are considered less vulnerable to fire than a comparatively long, narrow barrel would be. Further, since each shell acts in conjunction with its neighbour, it has been possible to eliminate all stiffening ribs and edge beams which would have presented surfaces open to attack from fire. The tie member, which would have been unavoidable had a rounded dome been constructed on the rectangular base, has been eliminated by the use of the four-sided dome in which the tie is, in fact, merged in the valley thickening. The whole roof thus presents a continuous surface, broken only into curved



A corner of the warehouse which clearly shows the unusual shape of the shell roofs. Edge beams are prestressed in both directions, placing the entire roof in compression.



Part plan of the roof, showing the arrangement of the prestressing cables.

Prestressing cables: – – – – – –

Additional prestressing: ....

planes, and with no actual projections vulnerable to fire.

The project was originally conceived in normal reinforced concrete, but the designer then carried it a stage further and determined to eliminate, as far as possible, any hair cracks in the concrete and so do without a waterproof covering to the roof. To this end, the reinforcement bars at the intersections of the domes have been replaced by prestressing cables and, by applying a tension greater than that necessary to counteract the effect of load, the whole structure has been placed in compression.

The prestressing was carried out on the Freyssinet system, each valley being stressed by a series of pairs of cables, each cable being made up of eighteen 0.2 in. wires. Transverse cables are the length of two domes. Longitudinal cables are the length of one dome, each being anchored on the outside of the supporting columns so as to transfer the tension from one dome to the next. Additional cables run the full length and width of the structure and they will provide additional protection against shear cracking should this be necessary.

Timber formwork was used: six wooden domes, each re-used ten times. After the concrete had hardened and the prestress had been applied, the forms were lowered by means of special jacks, passed under the valley, placed in position for casting the adjoining dome and then raised by jacks to the desired height. Eight domes were cast in a month.

The concrete has been left throughout as it came from the formwork. To complete the fire resistance of the building, special 'thermolux' glass was used in the lantern rooflights—glass which prevents a concentration of the sun's rays which might cause a fire. The four central panes, more fragile than the rest, are designed to break should fire occur and by acting as a chimney for the hot air below, to localize the danger.

An aerial view of the new cotton warehouse and its sixty shell concrete domes. The reconstructed portion of the pre-war warehouse continues on the right.

THOMAS HAWKSLEY

Portrait by courtesy of the Institution of Civil Engineers

In

SUNDERLAND'S CENTURY-OLD RESERVOIRS

a 19th century engineer's fine work gains new vitality from the application of 20th century engineering

CONCRETE SHELL ROOFS have recently been constructed over two reservoirs which help to supply Sunderland with its water. These reservoirs, known as Humbledon Low and Humbledon High Reservoirs, lie the one on the side and the other on the summit of a hill near the outskirts of the town. When they were built, the one in 1849, the other in 1874, the arterial roads were not there, cutting across the fields; nor were the villas that line them, clustering closer and closer until they become the suburbs and finally the streets of Sunderland.

Both reservoirs were built by Thomas Hawksley, that great and versatile engineer whose long life covered almost the whole of the 19th century, who was equally at home dealing with water supplies, gas or drainage, and who had original contributions to make to all three.

A remarkable man, this Hawksley. Born in 1807, the son of a Nottingham manufacturer, he was only 23 when he undertook his first civil engineering work—the construction of a new waterworks for Nottingham. After that, there was hardly a town of any size in the North or Midlands that did not owe him its water supply. Liverpool, Leicester, Leeds, Huddersfield, Durham were among the places where he installed reservoirs for gravity supply; in Nottingham, Derby, York, Darlington, Stockton, Southport, Northampton, Sunderland and many more—and then down to Coventry, Worcester, Oxford and westwards into Wales—he provided supplies based on pumping. Nor was his work confined to England—places as far apart as Stockholm, and Bridgetown, Barbados, owed him their new water supplies.

This is not the biography of a 19th century engineer, but a description of two contemporary roofs—but there are two stories told of Thomas Hawksley that are worth re-telling. One concerns his youth, the other his old age.

He was gas engineer at Nottingham at the time of the Chartist riots, when the gas-works

The concrete structure of shell roofs and end walls that encloses Humbledon High Reservoir. The irregular shape of this reservoir made necessary the flat-roofed portions at the ends.

were attacked by a mob who hoped to put the town in darkness. Hawksley marshalled his small staff, barricaded the entrance to the works, coupled up pipes, connected them to the gas supply and, says the account given in an obituary address, "offered to play through a nozzle a great tongue of fire on the attacking party, in addition to receiving them with shot and hot tar. On these defensive preparations being explained to the rioters they prudently retired from the works."

The other story is of an incident when Hawksley was 81, busy, respected and world-famous. A young friend of his was giving a scientific address at a town a hundred miles from London. On seeing the veteran engineer in the gathering, the friend asked him where he was staying. "Nowhere," replied the old gentleman, "I am too busy to stay away from work. But I came up by the afternoon express because I knew you would like me to be here to support you. I am now going back to London by the midnight train."

However, this is not the biography of a man, but a description of two roofs.

The reservoirs that Hawksley built in Sunderland at twenty-five years' interval both have puddle clay floors 18 in. thick and gravity section brick walls founded on 'gravel puddle' and backed with puddle clay of a minimum thickness of 2 ft.

Humbledon Low Reservoir, the earliest, is 130 ft. long by 98 ft. wide, and holds 800,000 gallons—its average depth is 10 ft. 8 in. In 1902 this reservoir began to develop cracks, and after a year was leaking at an alarming rate.

Repairs consisted of covering the floor, originally paved with 3 in. bricks, with three inches of concrete laid on bitumen sheeting, and lining the walls with 4½ in. glazed brickwork backed with bitumen sheeting, and the reservoir has remained watertight ever since. It was established that the cracking was due to mining subsidence—and, in fact, damages were obtained on this score from the colliery concerned. The High Reservoir was also subject to mining subsidence, but apparently had sufficient flexibility to accommodate itself to the movement. This reservoir is the larger of the two—with a capacity of 1,165,000 gallons, its measurements are approximately 160 ft. by 100 ft. and its average depth 12 ft. In shape, however, this is not a clean-cut rectangle—and a narrowing at the ends and a rounding of the corners complicated to some extent the design of the new roof.

It was in 1948 that it first became apparent that these two reservoirs ought to be roofed over. People living in the district noticed minute creatures in the water, which were found to be the larvae of a species of gnat which laid its eggs on the surface of the water. It was therefore decided to cover the reservoirs, but in view of the puddle clay floor and the unreliable subsoil, it was clear that supporting columns, which would be required for flat slab, or beam and slab roofs, would be unsatisfactory. The solution was to roof the two reservoirs with concrete barrels which would span from side to side, bearing upon the more stable foundations of the walls.

The roofs as now constructed consist in each case of three barrels of thin concrete, spanning the width of the reservoir—approximately 100 ft.—and 43 ft. 6 in., or thereabouts, in chord width. Ends are closed by stiffening spandrel beams, or walls, 9 in. thick.

At the Low Reservoir, the outer barrels have edge beams 3 ft. 6 in. deep and 9 in. thick, which bear upon the existing end walls of the reservoir. At the High Reservoir the irregular shape required different treatment, and so the narrower portion at each end has been given a flat roof which spans between the end wall of the reservoir and the beam of the outer barrels.

The most outstanding feature in the construction of these roofs, which are orthodox in design, is the degree of control applied to the mixing and placing of the concrete.

Two mixes were used in the work—a 1 : 1½ : 3 mix with aggregate of ⅜ in. maximum size for the shells, the valley beams and edge beams, and a 1 : 2 : 4 mix with aggregate of ¾ in. maximum size for the gable ends, the foundation slab and the upper part of the Low Reservoir edge beams.

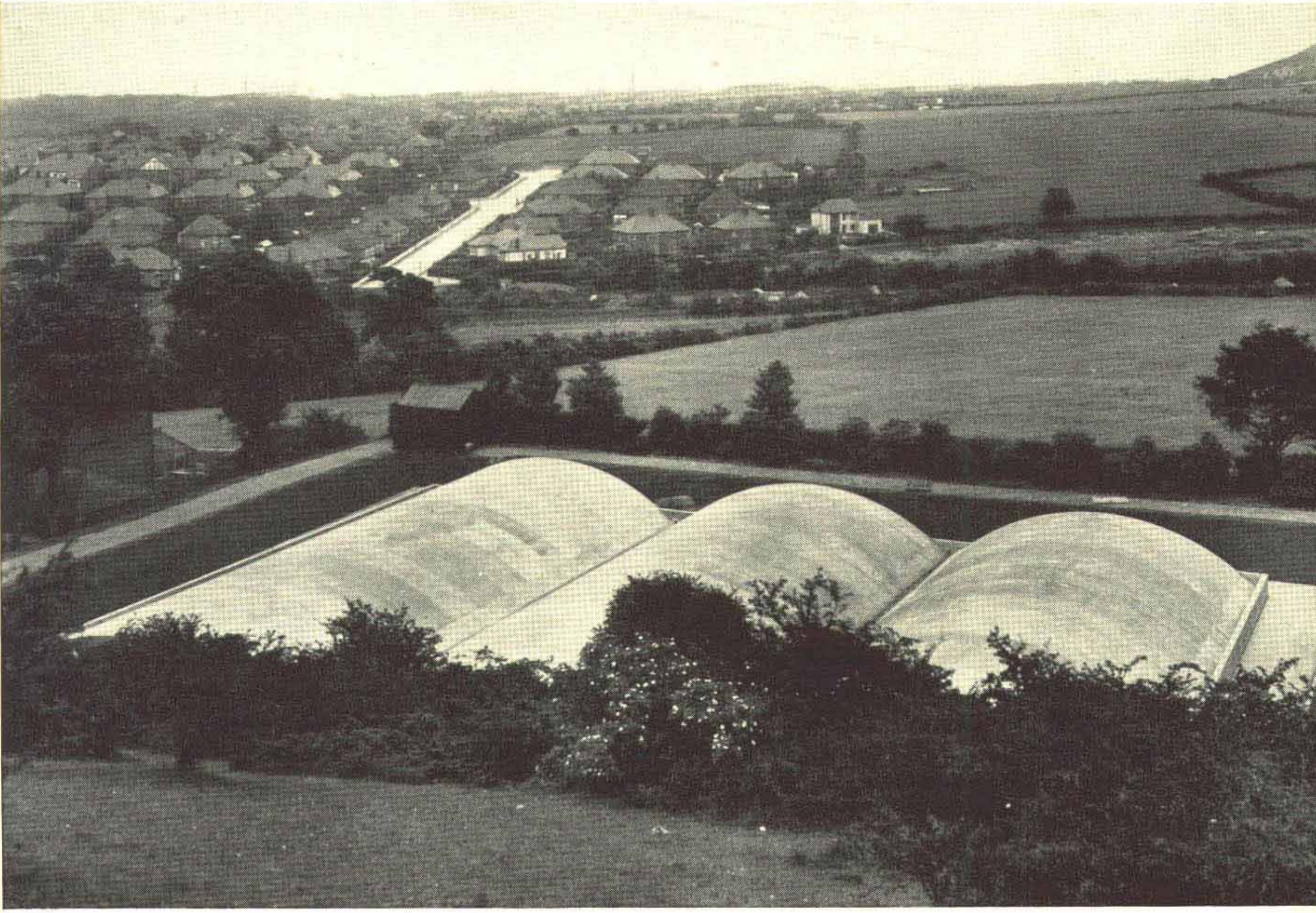
Tests were made on samples taken from 40 miles around before the aggregate was finally chosen and special precautions were taken with regard to work in cold weather. No concreting was done at a temperature of less than 40°F. and no concreting was started for at least 24 hours after a temperature below freezing point had been registered. The use of chemicals to counteract freezing was prohibited.

The concrete was batched by volume, the mix being based on a whole 1 cwt. bag of cement. To prevent inaccuracies caused by the bulking of damp sand, fully saturated sand was used throughout. This was obtained by gauging the sand in a watertight gauge box containing a given quantity of water.

The grading of the coarse aggregate was the subject of special attention. Lorries were only permitted to carry one size of aggregate at a time, and on arrival at the site each lorry load was delivered direct into the appropriate storage bin. Separate gauge boxes were provided for each size of aggregate, eliminating any likelihood of error.

The proportion of water in the mix was as carefully controlled as those of the cement, sand and coarse aggregate. The standard tank and gauge fitted to the normal mixer was thought to be insufficiently accurate to give proper control, and a special water gauging apparatus was evolved to deliver an exact quantity of water into either the mixer drum or the sand gauge box. The apparatus was simple and could be easily worked and understood by a mixer driver, and had the added advantage that any error in its operation could be easily noticed by the engineer in charge.

In addition to these 'field' precautions, a laboratory was set up on the site where test cubes were prepared and where the consistence of the concrete was measured by the compacting factor test. This test, which was used for greater accuracy in place of the slump test, is a means of measuring the workability of concrete. It can normally be relied upon to indicate a 2 per cent. change in the water content of a mix. The apparatus consists of two bucket-shaped containers with trap-door bottoms,



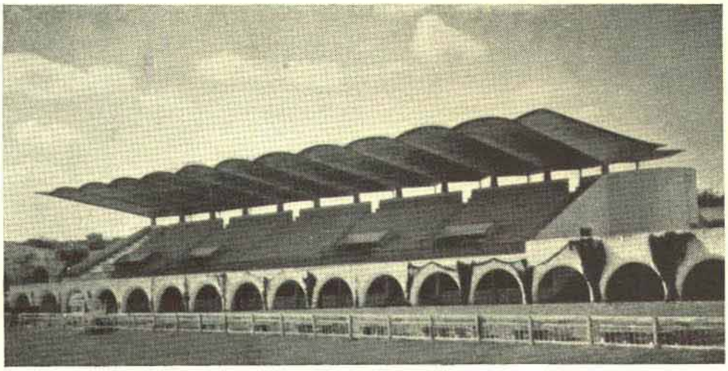
Looking down on the shell roofs of Humbledon Low reservoir, on the slope of a hill outside Sunderland.

fixed one above the other, and a cylinder below the lower one. The concrete is placed in the upper container, allowed to fall through to the second, and from there to the cylinder, where the surface is struck off and the concrete weighed. This weight, when related to the theoretical weight of fully compacted concrete, gives the 'compacting factor,' which varies noticeably with very slight variations in water content.

The concrete was entirely compacted by hand, and with the water-cement ratio of 0.455 for the shells and 0.508 for the leaner mix, a dense, close texture was obtained without difficulty.

Proper curing was looked upon as extremely important, and the roofs were kept covered with damp hessian for seven days after placing. Formwork was not removed from the soffits of the Low Reservoir barrels until after three weeks—after six weeks, for the valley beams. At the High Reservoir, which was concreted in summer, a shorter delay was possible—the soffit formwork was removed after two weeks and that of the valley beams after four weeks. The finish, on removal of the formwork, was found to be uniformly satisfactory, and the roofs have been left uncovered.

The reservoir roofs were constructed for the Sunderland and South Shields Water Company, whose Engineer and General Manager, A. G. McLellan, B.SC., M.I.C.E., M.I.W.E., was responsible for the works which were carried out on the site under the supervision of the Company's resident engineer. The contractors were William Moss and Sons Limited. The shells were designed by Barrel Vault Roofs (Designs) Limited.



Winged canopies at Madrid racecourse

STILL ONE of the world's most remarkable shell structures, the grandstand at the Madrid racecourse was completed sixteen years ago. Since 1936 shell design has made advances in every country, but the brilliance and daring of this Spanish work are still unexcelled—are, in fact, still unequalled.

The great upswept wings of the cantilevered canopy seem poised in flight—engineering here appears to have overcome gravity. Three separate canopies shade the grandstand, made up, two of twelve shells, one of six; doubly curved, they soar upwards from the supports as they spread 42 ft. over the tiers of seats.

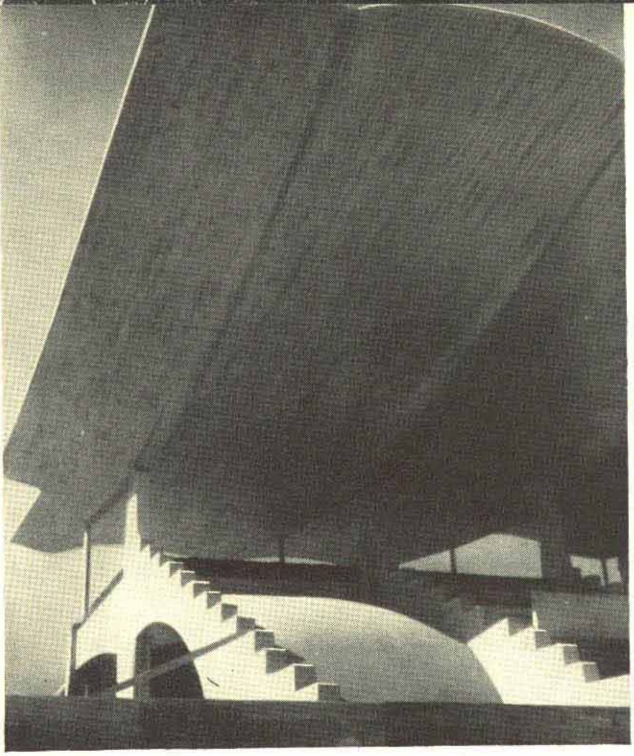
The superb invention of Torroja has here extracted the utmost from his chosen material, concrete; no other material could have given such a structure—no other designer has. The following notes on the construction of the grandstand are taken from a paper by Eduardo Torroja, and give his own description of the work.

THE MOST STRIKING features of this structure are the cantilevered canopies, which consist of a series of shells without ribs, edge beams or joints, cantilevered 42 ft. from the supports. Their section is approximately that of a hyperbola (convex upwards), the surface being formed by a curved generator (convex downwards). Their thickness varies from 2 in. at the edges to 6 in. at the supports, with an increase at the valleys.

The shells are, in fact, not strictly hyperbolic in section, as this form would have produced a curved line of intersection at the valleys, and the architects who collaborated in the design (C. Arniches and M. Dominguez) were of the opinion that such a design would be too audacious for the aesthetic appreciation of the present age. The hyperbolic section was therefore altered in the region of the supports to produce a straight line of junction between the shells.

To anyone reasonably familiar with this type of structure it was obvious that this form of shell would be fully able to withstand the loads and satisfy the structural demands upon it, although on the other hand it was clearly impossible to make it function strictly as a membrane, without loads normal to its surface.

The full mathematical analysis of its behaviour would have involved an exceedingly complex calculation, even assuming that the surface was exactly that of a hyperboloid, and it was therefore decided that an exact strength analysis of the structure could not be carried out. This was, however, no reason for not adopting this form of construction, which with its light-



The great winged canopies seen from below.

ness, its aptness to the structural demands and its aesthetic appearance, was so admirably suited to the purpose.

Although a scale model test could have been made in the first instance, it was thought better to make an approximate analytical investigation first, to determine the most convenient size and distribution of reinforcement and stresses.

Owing to the disproportion between the 42 ft. cantilever and the longitudinal spacing of supports at 16 ft. 6 in. centres, it was evident that the behaviour of the structure as a cantilever was far more decisive than its behaviour as a beam between supports. But, owing to its unusual beam section, its analysis as a cantilever could not be carried out by ordinary calculation methods. In addition to the vertical shear forces normally considered in beams there would in this case be very considerable horizontal shearing forces within the section. Consequently, to enable the structure to be analyzed as a cantilever, and particularly to determine the required reinforcement transverse to the shearing forces, it was necessary to know the approximate distribution of shear stresses.

As is well known, this problem can be solved for a cantilever beam of constant section with an applied load at the end or sufficiently far from the section considered. An approximate solution could have been obtained by considering this structural shell as a beam of this kind—that is by ignoring the slight effect that the change in section near the root might have.

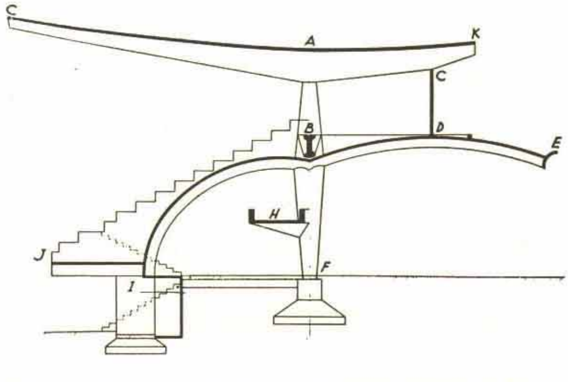
This could have been acceptable if the support of the structure had been along the whole area of the section. But since this is not the case, it is clear that in the neighbourhood of the support the law of stress distribution must be entirely different from what it would be if the classic theory were applied. Nevertheless, (except in the zone near the points of support), the application of this theory seems to be sufficiently justified at least as an approximation.

Once the stresses have been obtained in this way, the transverse and longitudinal reinforcement can be distributed in the most convenient manner, even though it may, in many cases, interfere with the assumed homogeneity and isotropy which is the basis of the theory.

But this solution is of no use even as an approximation for the most highly stressed sections near the support. Here the concentration of stress and its discontinuity are quite incompatible with the assumed hypotheses. In this zone transverse sections may undergo unknown and very considerable bending stresses, and shear stresses may diverge from previously mentioned laws.

Furthermore, constructional requirements made it necessary to fix construction joints, and it seemed most obvious to establish them along the crown generators, to reduce the risk of permeability and to remove them from the points of support. For this reason and because of the way in which the shell was to function, it seemed advisable that the longitudinal reinforcing rods (which are by far the most important) should not cross the line of the shell generator at the crown. Across this line there are only light reinforcing rods, to keep the two edges of the shell surface knit together. This arrangement of the reinforcement was also used for the end half-shells, which finish along the line of the crown.

It will be realized that though these investigations might give an idea as to the size and distribution of the reinforcement, they could not give the designer full assurance as to the strength of the whole structure. It was therefore decided to undertake scale model tests in accordance with the calculations. The contractors, however, offered to carry out a full-scale test. Since all the formwork, which was to be



Cross section through the grandstand. A–B–F : Main support, C–K : The canopy, which is pin-jointed to support A–B, C–D : Tie member, D–B : Gallery, B–J : Tiers of seats, I : Secondary support to tiers, I–J : Gallery opening on to track, I–F : Inner gallery, H : Service gangway, F–E : Betting hall.

re-used thirty times on the site, would have to be tested in the workshops to ensure correct adjustment, the cost of making a full-scale test on a single section amounted to little more than the cost of the concrete (about 20 cu. yd.). Most of the steel was recovered.

A test section was therefore constructed and loaded to destruction. The deadweight was about 57.3 lb. per sq. ft. and the estimated overload 14.3 lb. per sq. ft. This gave a total bending moment at the root of 420 ft. tons. The actual overload at which failure occurred was 124 lb. per sq. ft., corresponding to a root bending moment of 1100 ft. tons. This corresponds to a safety factor of 2.6 for the total load and 8.6 on the overload.

There was little strain at the moment of failure.

During the process of loading (which was done with sandbags) the instruments fitted to the compression side recorded normal progressively increasing stresses, which finally went beyond the range of the dial.

The zones subjected to tension cracked very extensively during the later stages of the test. These cracks were well distributed. The maximum deflexion at the end of the roof was more than 6 in. and the maxima actually occurred at the extreme edges of the half shells, which in this test structure lacked the supporting thrust of adjacent shells.

The whole structure thus exhibited good elastic behaviour. Failure was reached without much transverse strain in the sections near the supports, where there had been the greatest doubt as to the possible behaviour of the structure, and where the thickness had consequently been increased to 6 in.

Failure was very clearly due to too great a bending moment over the support. Deformation occurred very rapidly, and full stressing of the material was rapidly extended from the tension to the compression flanges, as was to be expected in a member with a normal amount of reinforcement. It was not possible to establish whether the final failure of the reinforcement was normal, or due to sliding of the rods in the cracked concrete of the shell, but this was of no importance from the safety point of view owing to the high breaking load that was ultimately reached.

Thus, backed by an assurance that a test to destruction on the actual structure provides, it was decided to proceed with the construction of the roof in accordance with the design, without making any modifications whatever.

A full-scale test of this type is particularly to be recommended in all those cases (more frequent than is generally realized) where the work consists of a number of identical units, and therefore the erection of a full-scale section would only involve a small percentage of the total cost.

This structure was practically finished by July 18th, 1936, and during most of the Civil War was very close to the front line. As a result all parts of the structure, but especially the roof, suffered repeatedly from shelling. Many of the holes left the main reinforcement exposed, but in spite of this none of the shells collapsed and repairs were easily made. There was one exception. In one section of the roof a direct hit caused considerable damage near the point of support, and cracks extended deeply into the section. These cracks were inclined in the direction of the main compressive loads and a superficial repair would have been dangerous. It was therefore thought advisable to demolish the damaged area, corresponding to the extreme ends of the roofing, and add small reinforcing flanges on the top at the joints.

The outer surface of the canopy has been finished with a waterproofing paste. Elsewhere, the concrete is for the most part exposed and merely painted. Even without paint, however, its appearance is good, thanks to the excellent formwork. This consisted of planed boards with tongued and grooved joints. Curvature has been designed to permit the use of standard boards for the top surface ; slightly narrower boards were used for the lower surface where the curve was greater.

Peterborough, *that ancient Fenland city, is also a modern city with a progressive approach to building. Its up-to-date* ***Technical College*** *has roofs of strongly arching northlight shells*

IT IS A STRANGE country, here in the Fens, where the rivers run higher than the land and the roads are hoisted on embankments. From these raised roads the endless fields spread out below flat as the sea, to a horizon that is round, as the sea's is. Here is some of the richest land in England, yet holding its riches on a knife edge. Balanced precariously between prosperity and disaster, these moist fertile fields only exist by the constant work of pumps raising the oozy water from a network of small dykes to larger and higher ditches, and up again to the embanked rivers and canals—the Fenland's 'drains.' The Fens are drained, tamed and civilized, but the work of draining and taming and civilizing has never been done once and for all—only unremitting vigilance holds them to these domestic ways.

This domesticity is very far from the Fens of history, a place of peaty marshes, meres and reed-grown waterways. From the days of the Vikings to the days of the Stuarts, Fenland was a place apart, with its own ways and customs, a misty land of amphibious people who lived on fish and wild fowl, their crops the reeds and rushes.

Islands rose from the marshes—rich islands of lush pastures and cornland, bright fruit trees and tended gardens, crowned by the great abbeys that made this land famous throughout the middle ages. Ely, Crowland, Thorney, Ramsey, they rose golden from the reedy swamps, Peterborough, the Golden Borough, richest of them all. Hereward the Wake sacked Peterborough, the abbey as well as the town, when a Norman Abbot had filled the place with Norman monks. Then he drove on to the island of Ely, to make his last stand in the 'Camp of Refuge' which could probably have held for ever if a traitor had not revealed the secret way across the Fen.

The Abbey Church of Peterborough grew and gained in beauty as the centuries passed. To-day it is the centre of a wide and pleasant town that is ringed with fantastic, smoke-blurred processions of tall thin chimneys—the brickworks that redden all this corner of the green countryside.

Brickmaking is Peterborough's principal industry but there are also a number of important engineering works established in and about this prosperous town, and Peterborough's greatest lack has always been adequate provision for the training of their apprentices—in fact, for the provision of any 'further education': the nearest technical college is 35 miles away. In 1943 Peterborough had one evening institute which provided for about 400 students from 14 onwards; in 1946 a temporary technical college was set up in two prefabricated buildings which were immediately filled to capacity by part-time students from jobs in industry. There is also an Adult Institute, opened in 1944, where over 1,000 students study all kinds of 'non-vocational' subjects, so that altogether, including the youth organizations and clubs, further education is provided, in one form or another, for some 3,000 people. But the demand has continued to increase, not only from Peterborough itself, but from the wide area of which the city is the natural centre. The two prefabs have been unable to provide facilities for mechanical and electrical engineering, among other things, and a new college was urgently needed when, in 1947, the Peterborough Joint Education Board obtained a suitable site and decided to hold a competition for a design for a college building.

The competition was won by David Jenkin, B.A., F.R.I.B.A., A.M.T.P.I., whose spacious open plan provides for buildings constructed in concrete and incorporating a number of shell structures.

The site as a whole is spacious and lovely, and the finished college will extend over wide grounds with tall trees scattered on the lawns.

Only a comparatively small part of the scheme is being carried out at present: an engineering wing and a building trades wing, linked by a drawing office block which, for the time being, will also house classrooms and administrative offices. In line with this 'link' block is the boiler house building, and all four structures have northlight shell concrete roofs. The second stage of the scheme will be dominated by a large twelve-storey block that will house classrooms, laboratories and domestic science and art rooms.

The parallel engineering and building wings are roofed with a series of northlight shells (eight and nine respectively) with bent-up valley beams and wide overhangs. With all their grace their lines have virility, and the broader sweep of the drawing office and boiler house roofs has the same quality—a line that is forceful as well as graceful, and that marries happily with adjoining flat roofs and sharply tapering, free-standing facade columns.

The shells in the two workshop wings are constructed in two continuous spans, in the building wing of 33 ft. 4 in. and 40 ft. 4 in., and in the engineering wing of 35 ft. 10 in. and 40 ft. 4 in. respectively. The inequality of span is due to the placing of supports at one side of a central corridor which runs the length of each wing. Heating and ventilating plant is all housed within the depth of the shell roof over this corridor, in alternate bays.

The down-turned top edge beams and the upstanding gutter beam slope at an angle of 55°, in the plane of the glazing. The beams are part of the shell structure and act with it, but an unusual feature in these two wings is that the upper edge of the shell is not supported by struts.

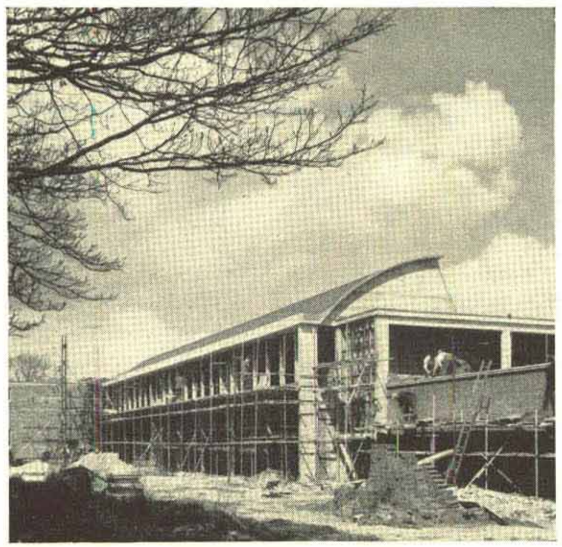
The 120 ft. long shell roof of the two-storey office block is in three continuous spans, of 45 ft., 45 ft. and 30 ft., and in this case struts occur at the points of support. The roof over the boiler house, which is 45 ft. in span, also has propped edges.

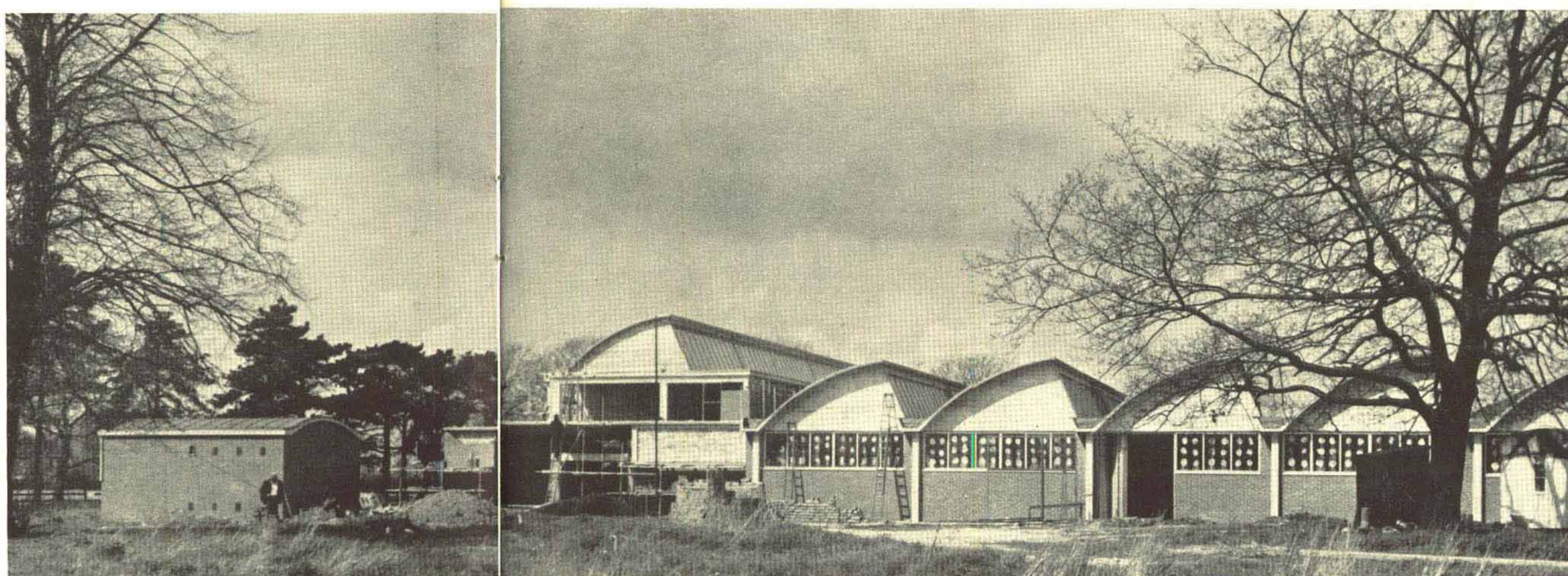
At the front of the drawing office block there is a lower flat-roofed section, containing corridors, and here the projecting roof is supported on columns of unusual and attractive shape. Like elongated triangles, they taper to top and bottom on the inside only, standing free of the wall except at first floor level—their widest point—where they form a bracket to carry the floor beam. Their width at this point is 2 ft. 6 in., and at the top and bottom only 8 in.

Wherever rendering is not to be applied, the concrete consists of a special mix made with broken brick dust and many of the surfaces are being tooled to expose the aggregate. In colour it is a pleasant warm pinkish tone, and the tooled surfaces have a grained texture that, without being too coarse, should weather well. Precast concrete slabs of the same mix, similarly tooled, are being used to face parts of the drawing office block and the boiler house. Infilling walls in the workshop wings are brick; gable ends are to be rendered.

All the shell roofs are copper covered and internally are finished with sprayed asbestos.

A small electricity sub-station in the grounds also has its shell roof—in this case a symmetrical barrel with up-curved edges—and another interesting building, which stands besides the concrete approach road, is the bicycle shed, constructed with mushroom head columns and flat slab roof. The imagination that has gone into the design of these two subsidiary buildings is typical of the whole college; the impression throughout is of a building on which care and genuine feeling have been expended. It undoubtedly owes much to close collaboration between the architect and the engineers, Ove Arup and Partners. Contractors are E. H. Burgess Limited.





Above: The forceful curve of the drawing office roof—shell concrete covered with copper. Administration offices will be temporarily housed in the flat-roofed and large-windowed wing to the right. Right: One of the engineering wings with the drawing office building behind. On the left is the electricity sub-station, a pleasant small building with its own shell roof.

The first prestressed shell building in England:

THE FROPAX FACTORY, KING'S LYNN

JUST OUTSIDE King's Lynn is the quick-freezing factory of Fropax (Ware) Limited, producers of frozen foods. Here shell roofing has been used on the three principal buildings—the garage block, the boiler house and the main factory which houses the quick-freeze plant.

The garage block is roofed by a single barrel 28 ft. wide and 146 ft. long, spanning continuously over supports spaced at intervals of 45 ft., 56 ft. and 45 ft. The barrel roof of the boiler house spans a length of 36 ft. Like that of the garage it is 28 ft. wide with a radius of 20 ft.—measurements which are standard throughout the factory buildings.

It is the main factory, however, that presents the real interest of this job: it is the first building to be completed in this country in which prestressing is combined with shell construction.

The roof consists of seven 28 ft. wide shells, which span a length of 112 ft., giving a completely clear floor area of 196 ft. by 112 ft. As the building—in the low-lying Fen country, close to the River Ouse—has had to be constructed on piles, this reduction in the number of supports has had the further advantage of bringing about a considerable saving in piling.

The barrels are all of concrete $2\frac{1}{2}$ in. thick. The prestressing occurs in the edge beams which have thus been enabled to span the 112 ft. distance with a depth of only 36 inches and a width of 8 inches.

The beams were post-tensioned on the Magnel-Blaton system. Straight cables were used and, to gain the maximum advantage from the prestressing the beams themselves have been cambered along their length with a rise of 38 inches in 112 feet. The barrels are thus given a curve in two directions—an outline which here is, in actual fact, that of any beer barrel or wine cask.

As the architect required a straight soffit to the external edge beams, these beams, which are considerably deeper than the internal ones, are not curved but are stressed instead with parabolic cables. Internal edge beams were stressed with 64 wires, each of 0.276 in. diameter, and end beams with 40 similar wires.

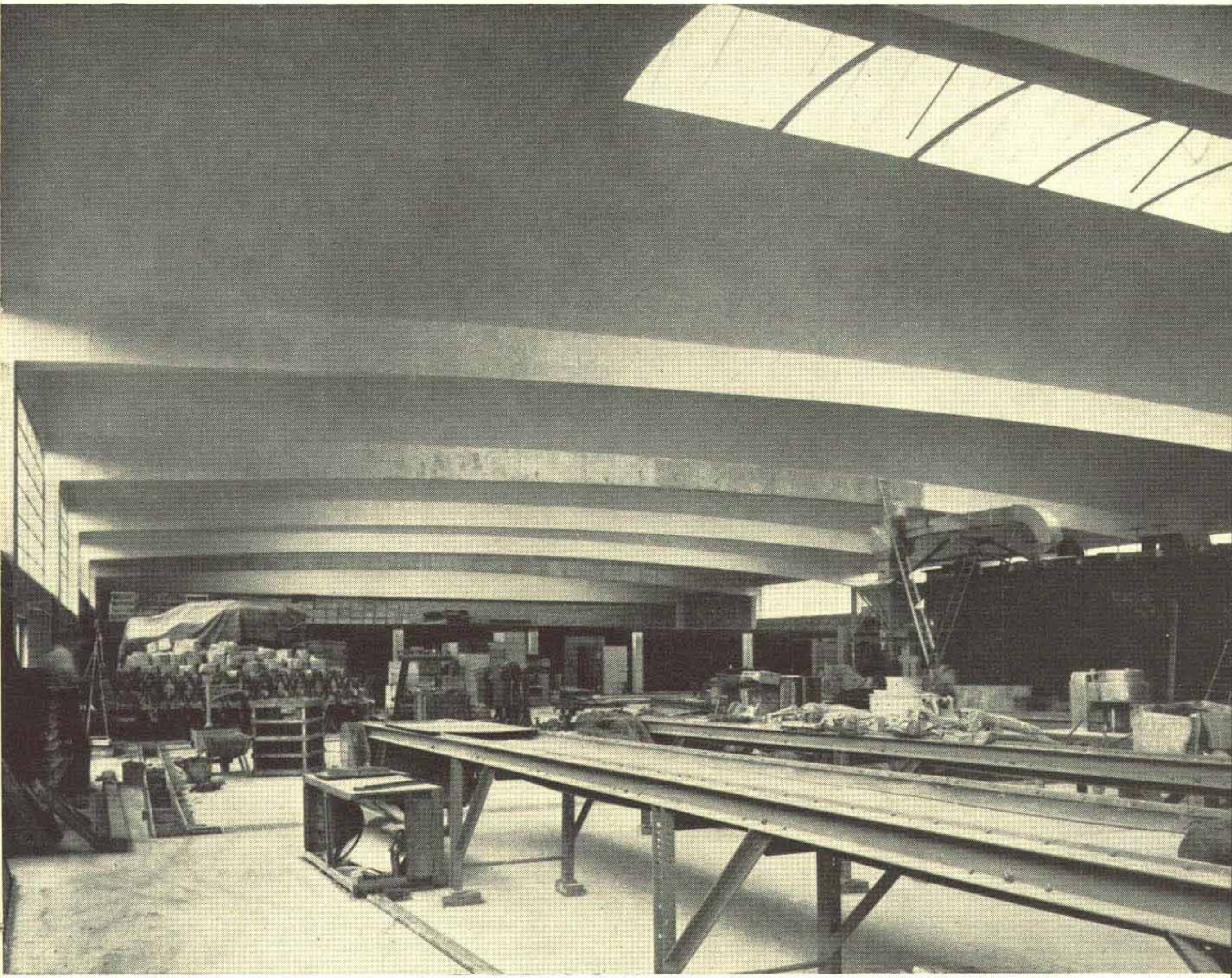
Resin-bonded formwork was used for the shell concrete and was found to give a very clean finish with close-fitting joints.

The concrete was placed in 28 ft. bays, and to enable the formwork to be struck and moved on without undue delay, small ribs were cast on the outside of the shell at 28 ft. intervals and the roof at these points supported on tubular steel scaffolding which was left in place until construction was completed.

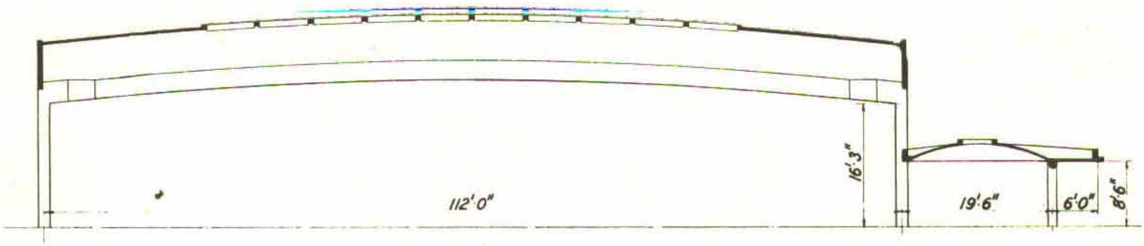
There are no expansion joints in the roof, as the columns were considered sufficiently flexible. Externally it is covered with three layers of waterproofing felt and a continuous top light is provided along the crown of each barrel. It was found that standard patent glazing was easily adapted to the longitudinal curve of the roof. Internally the roof is finished with 'Snowcem.'

In order to prevent frost-heaving of the ground, the cold store was raised up on sleeper walls above the floor level, allowing a full circulation of air below it.

The contractors for the work were Holst and Company Limited. The design of the roofs was carried out by Chisarc and Shell "D" Limited for whom H. G. Cousins, B.SC., M.I.C.E., M.I.Struct.E., acted as consulting engineer. The prestressing equipment was supplied by Stressed Concrete Design Limited.



The interior of the factory, showing the curved outline of the prestressed edge beams and the double curve of the shells.



LONGITUDINAL SECTION

Built entirely of reinforced concrete,

the rubber factory at BRYNMAWR

is of its kind a masterpiece—remarkable alike for its imaginative exploitation of the material's every possibility and for the identity of purpose which animated engineers and architects

SO MUCH has been written about the factory at Brynmawr that there can be few facts about it that are not already known.

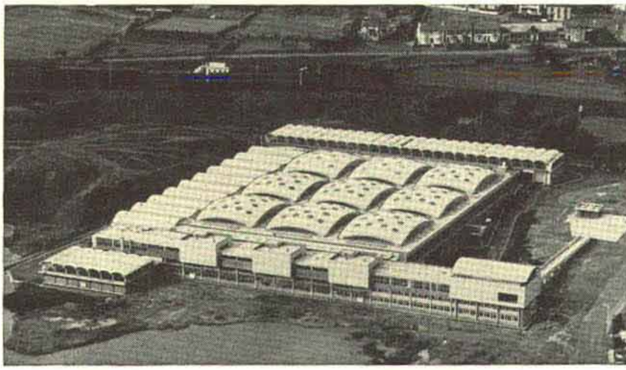
The circumstances of its siting are known: a well-known firm's co-operation with the Government's scheme for bringing new industry to the valleys of South Wales, and the fortunate locating of a site easy of access, central to four valleys, close to ample water supply, well-served by buses. One thing, though, of which little has been told, is of the loveliness of these valleys in the Spring. How green, indeed, is that eastern valley that runs up to Brynmawr, frothed with may blossom, yellow with buttercups in the deep grass, rich with the multitudinous greens of sunlit trees, and behind, the rounded hills. This valley is little touched, visibly, by the mines. Its neighbour, the western valley, has its string of rusty pitheads every few miles and a grey little townlet clambers the hillsides at each pithead, but between them the green asserts itself, the green that in time turns every spoil dump into a grass-grown hill.

The factory has been described in detail in the technical press and its construction is known: the central production area roofed with its nine thin concrete domes, flanked on three sides by the shell-roofed 'drug room' and 'mill room,' and the cubes of the cloakroom block.

Its dimensions are known: its extent of 325 ft. by about 450 ft., and its main production area of 77,000 sq. ft.

So familiar are these things that after climbing that surprising green valley the sight of the factory, lying on the edge of the little town in its hollow, is like the sight of an old friend; its nine square white domes gleaming in the sun, it lies there as familiar as the plan so often seen on paper.

Then the approach: photographs have given familiarity to the ramp leading up to the shell-roofed entrance block; to the long glass and brick wall on the right, topped by the flat white domes and interrupted by the brilliant concrete staircase with its turns and angles; to the small high shells of the drug room roof across the end.



An aerial view of the factory at Brynmawr. The main production area takes up the centre, with the drug room behind, the mill room on the left and the entrance ramp on the right. The small shell-roofed wing in the foreground is the printing and spreading room, separated from the main body of the factory because of the greater fire risk in this department.

At first glance this is all familiar. But how little a first glance tells, and how little of the Brynmawr factory is contained in that photograph familiarity. Nothing but the place itself gives a true idea of its quality.

The long ramp up to the left is the pedestrians' way in and the entrance hall with its racks of clocking-in cards is the common entrance for all the staff, from manager to machine minder, as well as for visitors.

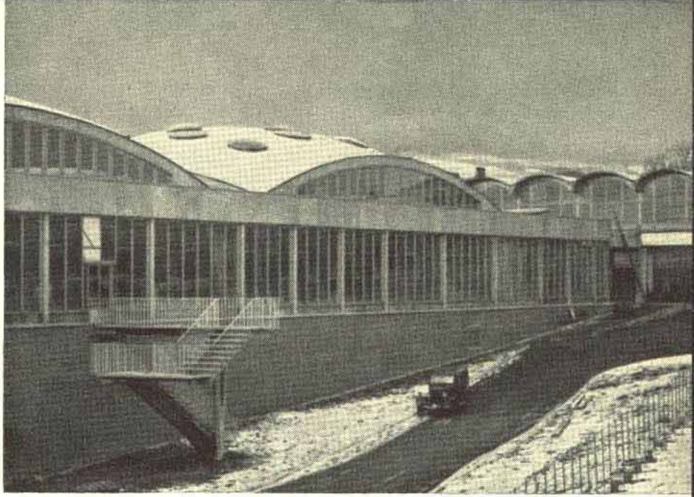
The goods entrance is to the right, at ground level. This is the entrance to the 'drug room'. Here the immediately-required chemicals and dyes are stored and are mixed and treated in bright yellow and red hoppers while the bales of raw rubber and the 'drugs' not immediately wanted go down a sloping ramp to the main store. From the hoppers and vats go the little skips of chemicals, and the little skips of raw rubber, on their roller conveyors, to pass, at the angle of the building where drug room joins mill room, into the jaws of the 'Banbury' machine which mixes the materials with carbon black and crushes them to a plasticine-like mass before chuting the lump 18 ft. down to be pressed between its two great steel rollers, at mill room ground level.

Three times the lump is pressed into sheets before being rolled and passed on to its next process—the presses and calenders in the mill room which turn out rubber sheeting and flooring strips and tiles of all kinds. A conveyor connecting each of the larger presses—in a row along one side of the mill room—carries the prepared rubber up again to the first-floor level main production area, where it is turned into the finished product.

The drug room is a long, comparatively narrow building, 331 ft. 6 in. long and 44ft. 7½ in. wide, and high, to accommodate the height of the Banbury machine and an overhead gantry crane. It is roofed with narrow, high-arched shells spanning its width—twenty-six of them in the whole length—carried on columns that narrow as they rise to crane rail level, tapering on the outer face, straight on the inner. Above the crane rail they slim again to a circular section shaft.

This room, little more than a storeroom, not much lived in or worked in, is decorated simply in light grey throughout, with shell soffits asbestos-sprayed off-white. Colour comes, willy-nilly, from vats of brilliant dyes, and from the vivid yellow and red of weighing machines and the turquoise blue of the walls flanking the yellow Banbury.

At the Banbury corner, drug room and mill



The " approach " side of the factory, showing the domes and glass of the main production area and the masterly little escape stair of cantilevered concrete that breaks the long line of the storeroom wall below.

room meet, and the junction is effected by carrying the last five barrels of the drug room on a reinforced concrete 'Warren girder' type of beam that surprises by its delicacy. A member 64 ft. long, and some 13 ft. deep, it carries not only five of the drug room barrels, but the connecting section of roof at the end of the mill room, the mill room crane rails and a walkway. Painted white, it is a lovely piece of concrete, its lines and proportions so balanced that lightness seems its outstanding quality.

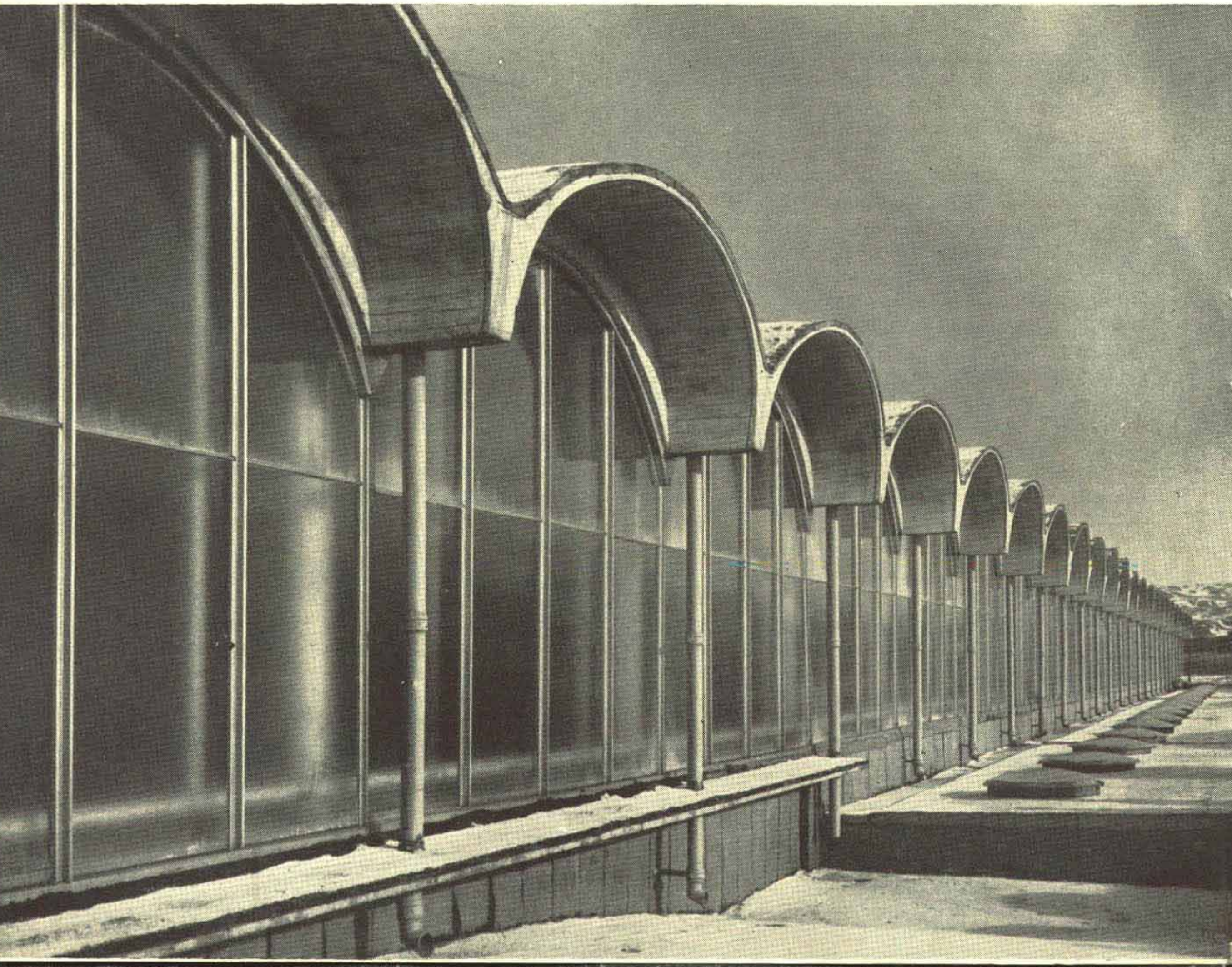
The mill room is lower and wider than the drug room and the shells of its roof are also quite different in their proportions. Here ten barrels, each thirty feet wide, span the width of 63 ft. 9 in. As in the drug room, glazing runs right up to the shell, and the place is very light. And here there is colour too. Walling, below the glazing in the outer wall, and below a horizontal panel of grooved beige-painted concrete on the inner, is painted dark blue. The end wall is grey and here, in the centre, the lift shaft block stands out in vivid leaf green. Machinery is mainly grey with safety and grab-rails of bright orange.

At the far end of the mill room is the opening into the basement storeroom, itself on three different levels connected by sloping ramps. This basement is a revelation. Here, indeed, is the first real revelation of the Brynmawr factory. The drug room has charm, with its high-arched shells and its slim columns; the mill room is bright, airy, a sound shell-roofed job; the whole thing is clever in its use of levels, its use of colour, its use of that surprisingly slender 'Warren girder', and of the shell roof itself. Here in the basement is the same care, the same

loving attention to detail, the same supremely efficient use of material, even where there is none to see and admire. Here in the dim half-light are the smooth, mushroom-headed columns that carry the main production floor, and, all superfluous mass pared away, the amazingly narrow, shapely columns that carry, ultimately, the domes of the roof. And all cast in beautiful concrete, untreated and unpainted, revealing its small, regular board marks.

Now follow the staff, up the long ramp to the entrance hall with its turned-up shell roof. This hall is part of the south-side block of the factory which contains cloakrooms, offices and canteen, but, separately roofed, it has the appearance of a separate structure. The roof is a thin shell spanning 57 ft. and carried rigidly at each end on a concrete wall, beyond which it cantilevers 5 ft. Instead of forming an edge beam down each side the edges here tilt up from the springing,

Above: The interior of the drug room, roofed with its twenty-six shells of concrete. Much light comes from glass spandrels in both sides and a continuous strip of glazing in the outer wall. Below: The mill room shells, seen from the roof of the main production area. The small down pipes, painted dull green, give an air of almost Victorian daintiness to this vista of narrow arches.



projecting some 4 ft. The concrete of the gable end has a grooved finish, cast in situ against ribbed formwork. The main body of the building is faced with exposed-aggregate precast slabs.

Inside, the hall with its racks of cards is light and gay, with much glass, a scarlet end wall, and one stabbing column of sharp lime yellow. There is polished woodwork, a black and white floor and a ceiling painted in swirls and planes of blues and green and grey and outlined masks of white and scarlet. Into one wall project the water tanks of white-painted concrete; from the opposite side of the entrance leads the long corridor that runs the entire length of the building, cloakrooms and lavatories opening off it on the left hand side, and on the right the main production hall.

And here is Brynmawr's second revelation.

There have been photographs of this hall. There is one over the page. Maybe you are wiser not to look at it. The place it seems, can be captured by no camera's lens. There is suddenly a soaring, a whiteness, a space that is all light and air. A revelation, in fact.

Familiar, in theory, are those smooth domes, taut as a sheet pinned at the corners and pulling up with the wind. Familiar, too, are those double V's of slender columns that are the pins. But no familiarity has conveyed the lifting sense of space, and the breadth and clarity of light that is the first impression of this vast hall. Seventy-seven-thousand square feet, they say. But this is space itself, soaring up with those taut spread domes of light. There is light everywhere; light from the domes in the roof, light from their glass spandrels, light from the lanterns in the walkways, light from the wall windows, and through and beyond are the hills and the sky.

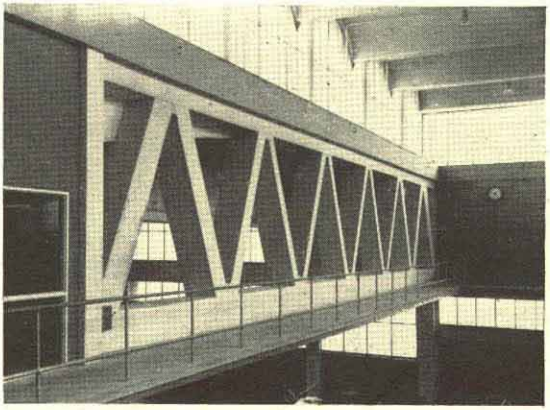
It is possible, of course, to pin it all down to a drawing board and some calculations. To say the domes are 83 ft. by 63 ft., the walkways between them are 12 ft. 9 in. wide, those V's of columns are 13 ft. high and 2 ft. 6 in. thick. The domes, you may say, have a rise of 8 ft. from springing to crown and are only 3 in. thick for all their span. And you will not forget that seventy-seven-thousand square feet of floor. You may tell of the fabulous number of square feet of glass that light the area, and your facts will all be there, but there will still be little to tell you how the facts have added up to this floating ship of luminosity in space and sky.

Decoration here is almost all white, with primrose yellow on the underside of the walkways between the domes, dull grey on the cylindrical ducts between the columns, and deep blue, the only sudden note, on the pipes between those ducts.

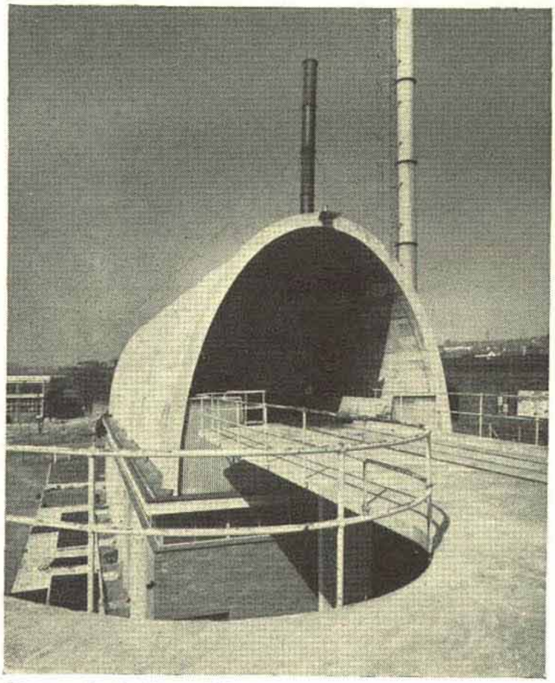
Artificial lighting has been as carefully watched as daylight. Circular dome lights in the roof are alternately glass for daylight, and metal covers, removable from the outside, holding bars of fluorescent lights. Fluorescent lights, again, outline the rectangular base of each dome. No one, they say, has ever wanted an individual light on his or her machine—and many of the processes are small-scale, fiddly work.

It was to deal with this multiplicity of processes, and in particular the quick changeover from one process to another, that the architects evolved an ingenious way of bringing services to the machines. All ducts are housed in the basement, under the flat slab floor of the production hall, and regularly spaced holes at

Top: The reinforced concrete Warren girder that forms the junction between drug room and mill room. Bottom: The mill room. On the right, below the wall panel of grooved concrete, is the vent room which houses the ventilation system and other services.



Above: The entrance hall block, with beyond, the south side of the factory, containing cloakrooms and offices. The entrance hall is faced with exposed-aggregate precast slabs in lightish grey. Below is brick; the gable end is ribbed in situ concrete. Below: The upper level of the boiler house, roofed with a steep shell of thin concrete.



Photograph: Architectural Press

frequent intervals connect them with whatever machine happens to be required. The change-over can easily be made during a weekend, without production being held up at all.

This care for practical detail is typical of the whole place. The architects will tell you that the factory grew out of the needs of the processes rather than that it was designed, deliberately, in such and such a way. And once the plan was established and the need was made clear, whether it chiefly grew in the mind of the architect or the engineer is something neither is well able to say. This building shows what can be done when both work in close collaboration from start to finish—when, in fact, they work as one and share in creating a lovely piece of work for the satisfaction of doing it.

There are two subsidiary buildings attached to the factory that, small as they are, still demonstrate this pleasure in creation. One is the boiler house, the other the pump house which feeds water from the reservoir to the tanks in the factory. The pump house, a simple cylinder with brick load-bearing walls faced with old random stone and with a ring of glazing round the top, has its own small concrete dome roof. Stiffened with umbrella-like spokes, each spoke supported on a slim shaft that forms a glazing bar, the little dome is painted blue inside. Its spokes and the brick inner walls are white. Outside, the roof is covered with green mineral felt.

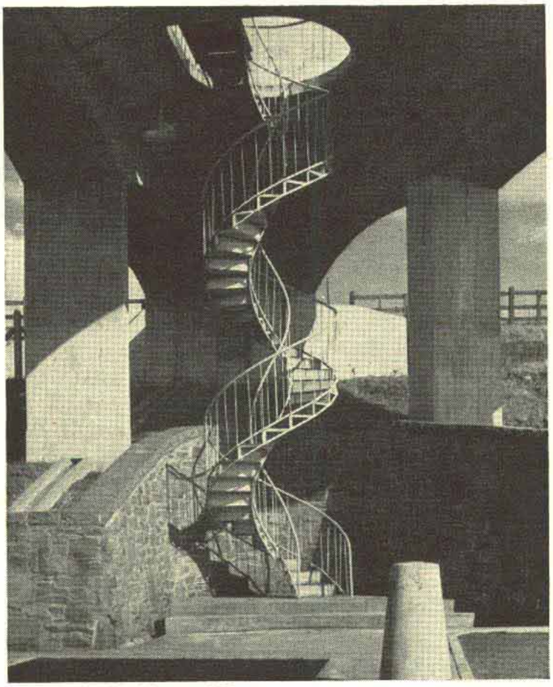
The concrete shell roof of the boiler house is semi-elliptical in shape, the minor axis being the base. The steep arch of concrete shelters trucks which run in at first floor level on a reinforced concrete bridge from the embanked railway alongside and deliver their coal direct into hoppers which form one structure with the roof and floor. The hoppers in turn feed direct into boilers at ground level. The lower part of the boiler house has infilling walls of brick divided by glazing from the concrete vault of the roof. Linking the ground with the first floor is an exquisite little spiral staircase, a free-standing helix without a newel, supported only at top and bottom. As delicate as lace, it is a lovely contrast with the concrete columns of the railway siding against which it stands.

Brynmawr's other external staircase is the reinforced concrete escape stair from the main production hall that makes a happy break in the long brick east wall of the 'basement'. Treads without risers are fixed to a strip of concrete

Above: The main production hall.
Right: The spiral staircase that leads from ground to upper level at the boiler house, twisting delicately against the concrete supports of the railway siding.

that rises to a projecting landing, turns and rises to another and bends back to the wall, all with no support other than a slim V-shaped column that carries the top landing. A brilliant piece of engineering design that must have delighted the architects.

They—the architects—were the Architects' Co-operative Partnership and the engineers who partnered them in this fine achievement were Ove Arup and Partners. The whole job was the work of two principal contractors. Holland & Hannen and Cubbits Limited were responsible for the storage basement with its mushroom columns supporting the main production area, for all the lower level construction, and for the boiler house. The superstructure of the main factory was the work of Gee, Walker and Slater Limited. The foundation work was carried out by the Cementation Company Limited.



Photograph: Architectural Press

A SCOTTISH PAPER MILL

has erected a shell-roofed building to house its supercalenders and finishing processes

THE WESTFIELD PAPER COMPANY LIMITED (one of a group of companies associated with the Inveresk Paper Company, Musselburgh) recently erected new supercalender and finishing houses at their Westfield Paper Works, near Bathgate, to accommodate preparation and finishing machines which are now being installed.

The supercalender house, which will also accommodate cutters and slitters, was erected first. It is a single-storey building, 180 ft. long by 60 ft. wide. The finishing house, which is divided into two storeys, is the same width and 150 ft. long. It was built as a continuation of the supercalender house, from which it is separated by a 9 in. thick brick wall acting as a fire break. The two buildings are thus housed under one roof with a total length of 330 ft.

The roof of the supercalender house is of shell construction, arching across the 60 ft. width. In outline it is semi-elliptical, with a rise of 16 ft., the height from ground floor to springing being 26 ft. The shell is supported at intervals of 30 ft. along its length by reinforced concrete portal frames 12 in. wide. These frames, which are 4 ft. deep at the crown, are 4 ft. 3 in. at the springing, and from these points the vertical members are tapered to a width of 2 ft. at the hinged bearings at the base. The general thickness of the shell is 3 in., increasing to 6 in. in contact with the frames. These portal frames project above the shell and outside the infilling walls thus providing an unbroken surface throughout the interior of the building and at the same time giving the structure architectural interest. At 60 ft. intervals double frames are provided to allow expansion joints to be carried right through the building. A stiff horizontal edge beam, designed to also act as a rainwater gutter, is provided at springing level. Cantilever brackets are incorporated in the upper sections of the portal frames to carry rails for a 5-ton travelling overhead electric crane.

The outside of the roof is covered with two layers of bituminous felt carried over the projecting portal frames, while the interior has been treated with an asbestos cement spray to give a coloured and textured finish.

The wall panels between portal frames are built with red facing brick, pointed on the outside and painted with white 'Snowcem' on the inside. Steel window sashes are incorporated in the panels.

The floor consists of a 5 in. thick concrete slab reinforced with steel fabric and finished with a $1\frac{1}{4}$ in. thickness of granolithic.

The concrete throughout the structure was composed of 1 part rapid-hardening cement, $1\frac{1}{2}$ parts washed Doune sand and 3 parts crushed whinstone graded from $\frac{3}{4}$ in. to $\frac{1}{4}$ in. It was consolidated by means of immersion vibrators. External formwork was used in the shell roof to a height of 7 ft. above the level of the springing, but above this the concrete was screeded.

Owing to the proximity of a stream to the east side of the building, a mass concrete retaining wall had to be erected along this side. This wall acts as a foundation for the legs of the portal frames and the brick panel walls on that side of the building. Elsewhere, normal concrete foundations were used.

The finishing house is a two-storey building with a height from ground to first floor of 12 ft. The portal frames and shell roof are identical with those of the supercalender house, except that the shell in the finishing house is broken at the ridge to provide a 'Lenscrete' light 10 ft. wide running the full length of the building.

The first floor, which is designed to carry a superimposed load of $3\frac{1}{2}$ cwt. per sq. ft., is composed of in situ prestressed concrete I-beams 18 in. deep by 12 in. wide with 6 in. web, placed at 2 ft. 6 in. centres. These beams carry a reinforced concrete floor slab $4\frac{1}{2}$ in. thick, including a 1 in. thickness of granolithic concrete. At the wall sides the prestressed beams are carried on reinforced concrete beams spanning between columns, while along the middle of the building the floor beams are carried on a 35 in. deep by 15 in. wide reinforced concrete spine beam, also spanning between columns. The wall columns are located at 7 ft. 6 in. centres, to coincide with the portal frames and window mullions but are kept independent of the frames. They measure 14 in. wide by 9 in. deep; their slenderness was intended to ensure that they would deflect when the floor beams were stressed. Double columns are provided at all expansion joints. The columns supporting the spine beam are at 15 ft. centres and measure 15 in. by 15 in. except where they are duplicated at expansion joints, when they are reduced to 15 in. by 9 in.

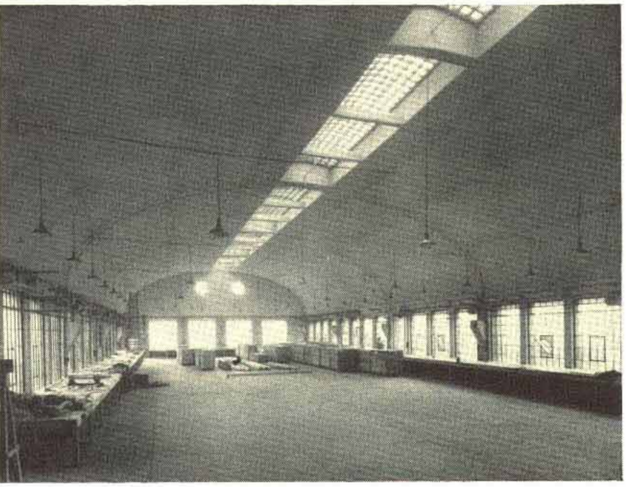
The prestressed floor beams were cast in situ on timber bases. The side forms were of steel and were struck 24 hours after the beams were cast, the timber bases being left in place and propped until the beams were stressed. The tops of the beams were castellated to provide a bond for the floor slab, which was cast on asbestos cement sheets spanning between the beams and left in place. Expansion joints were introduced along each outer wall and along either side of the central spine beam, the edges of the slabs at these joints being provided with steel angles and cover plates to protect them against wear by barrow traffic.

The concrete for the prestressed beams was vibrated by means of immersion vibrators. It was composed of 1 part rapid-hardening cement, $1\frac{1}{2}$ parts washed Doune sand and 3 parts crushed whinstone graded from $\frac{3}{4}$ in. to $\frac{1}{4}$ in., the water-cement ratio being 0.45. A minimum cube strength of 6,000 lb. per sq. in. at 28 days was asked for and obtained.

The beams were stressed on the Magnel-Blaton system by means of two cables located one above the other, each cable consisting of 32 wires 0.2 in. in diameter, the ducts being formed with the usual extractable rubber core. An unusual feature of the stressing operation was that although the cables took the form of a parabola in each half of the centrally supported beams, each cable extended continuously across the 60 ft. width of the building and thus took the form of two parabolic curves. Stressing was, nevertheless, carried out from one end only. The beams were stressed before the floor slab was laid and the effect of stressing was to raise them off their timber bases. They were then propped and wedged to their new camber before the floor was cast, the result being that when the concrete in the floor hardened and the props were removed, the beams and slab acted together as a series of T-beams and the floor slab took its share of the stresses set up by the superimposed load.

A 4-ton electric goods hoist, operating between ground and first floor, is located at one end of the building, and a reinforced concrete bridge, with a clear span of 55 ft. and a width of 8 ft. between parapets, connects the lift tower to the old finishing house on the further side of the stream. The bridge consists of two beams 4 ft. 6 in. deep carrying a 7 in. deck slab. The sides and roof are covered with corrugated asbestos cement sheets carried on reinforced concrete portal frames at 12 ft. centres.

Blyth and Blyth, M/M.I.C.E., Consulting Engineers, Edinburgh, designed the whole of the works; the contractors were Holst and Company Limited, of London and Edinburgh.



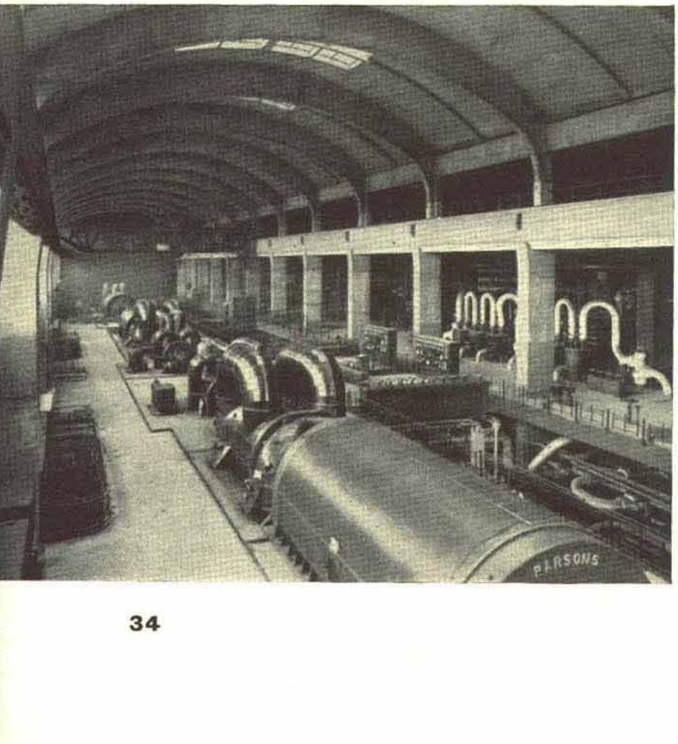
Interior of the new finishing house at the Westfield Paper Works. This is the upper floor of the two-storey building which joins the single-storey supercalender house. The two are under one roof.

SKELTON GRANGE

THERE WAS A TIME when all over the country cathedrals were being built to the glory of God. Our twentieth century cathedrals are more often dedicated to the glory of God's handiwork and man's achievement—an austere faith expressed in this century's typically austere construction.

Outside Leeds is that great modern cathedral, dedicated to the production of power—the turbine house at Skelton Grange. A year ago you could see it in its unbroken symmetry, a nave 800 ft. long and 74 ft. wide, columns soaring 80 ft. to carry its arched roof, and far away the open end wall traceried with scaffolding like some delicately glazed cathedral window.

Then, only the first section of the building—the first 400 ft.—had been completed. The further part, still wanting its floors and walls and machinery, captured a soaring sense of space; its immensities were awe-inspiring.



Floored and walled and equipped with its magnificent machinery, the first half of the turbine house is now in production and three 60,000 kW. turbo-alternators are already contributing their power to the grid. The completion of the second section is now proceeding and in due course the whole building will house six 60,000 kW. turbo-alternators and the associated boiler and auxiliary plant.

Skelton Grange turbine house was described in *Concrete Quarterly No. 7*, when the first half only was being erected. The three-inch thick shell roof, whose construction was described in that article, is carried on columns 5 ft. by 2 ft. 6 in. in section, and stiffened at 31 ft. intervals by arch ribs springing from the columns. From ground to crown the building rises 88 ft.; the operating floor is suspended 30 ft. up. Below are the massive concrete foundation blocks that carry the machines.

. The turbine house was designed and erected by Holst and Company Limited; Chisarc and Shell " D " Limited, for whom H. G. Cousins, B.SC., M.I.C.E., acted as consulting engineer, designed the roof. H. Arnold and Son Limited were responsible for the foundations. Consulting engineers for the power station as a whole were Merz and McLellan, in association with Sir Alexander Gibb and Partners for the civil engineering and building work. Main civil contractors are Marples, Ridgway and Partners Limited. R. A. H. Livett, O.B.E., A.R.I.B.A., Leeds City Architect, acted as consulting architect, advising on the treatment of the superstructures.

Left: One end of the completed turbine house at operating floor level, with the great turbo-alternators installed. Opposite: The turbine house under construction—a modern cathedral with its soaring columns and high-arched roof, the tracery of scaffolding across its open end reproducing the tracery of a stained glass window.

Bournemouth has made provision for its growing fleet of buses with a new garage roofed with

150 FT SPAN PRESTRESSED SHELLS

SOME INTERESTING information on the country's road transport situation is provided by the Ministry of Transport's annual *Census of Mechanically Propelled Road Vehicles.* This document shows that between 1938 and 1948—the ten years covered by the war, when one would least have expected such an increase—the number of buses and coaches in the country increased by 29 per cent. By 1950 there had been a further rise of 13 per cent., making an increase of 45 per cent. over the number of such vehicles on the roads before the war. Yet garage accommodation had hardly changed since 1938, and everywhere buses were being parked in the open or at best inconveniently housed in converted tram depots.

By 1948, the war-time standstill being relaxed, a number of Councils all over the country had put in hand plans for garage construction. Bournemouth, Sheffield and Lydney were among the local authorities who started construction of bus garages, all of them using the reinforced concrete shell construction, and the London Transport Executive also had important work in hand.

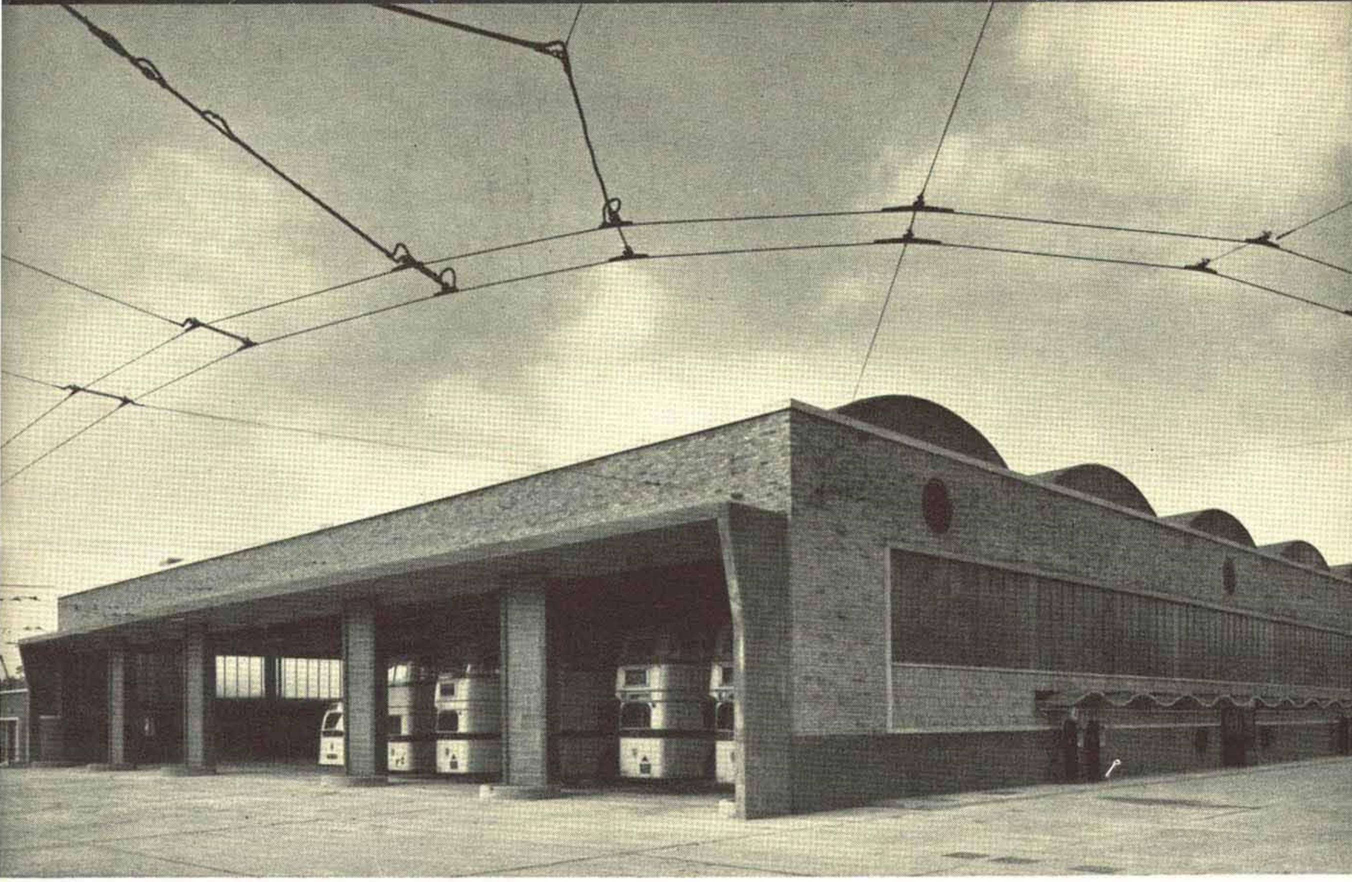
At Bournemouth even before the war the depots were inadequate for the Corporation's fleet of buses and plans had already been made for the enlargement and improvement of existing premises—plans never carried out because the war intervened. By 1948, however, it was clear that these measures would be quite inadequate, and that an entirely new depot would have to be provided. Bournemouth's growing number of vehicles was a fairly exact reflection of the increase in the country as a whole: from 68 buses in 1940, the Corporation's fleet had increased to 81 by the end of 1950, while their 104 trolley buses had become 127—in all 36 more vehicles to be housed.

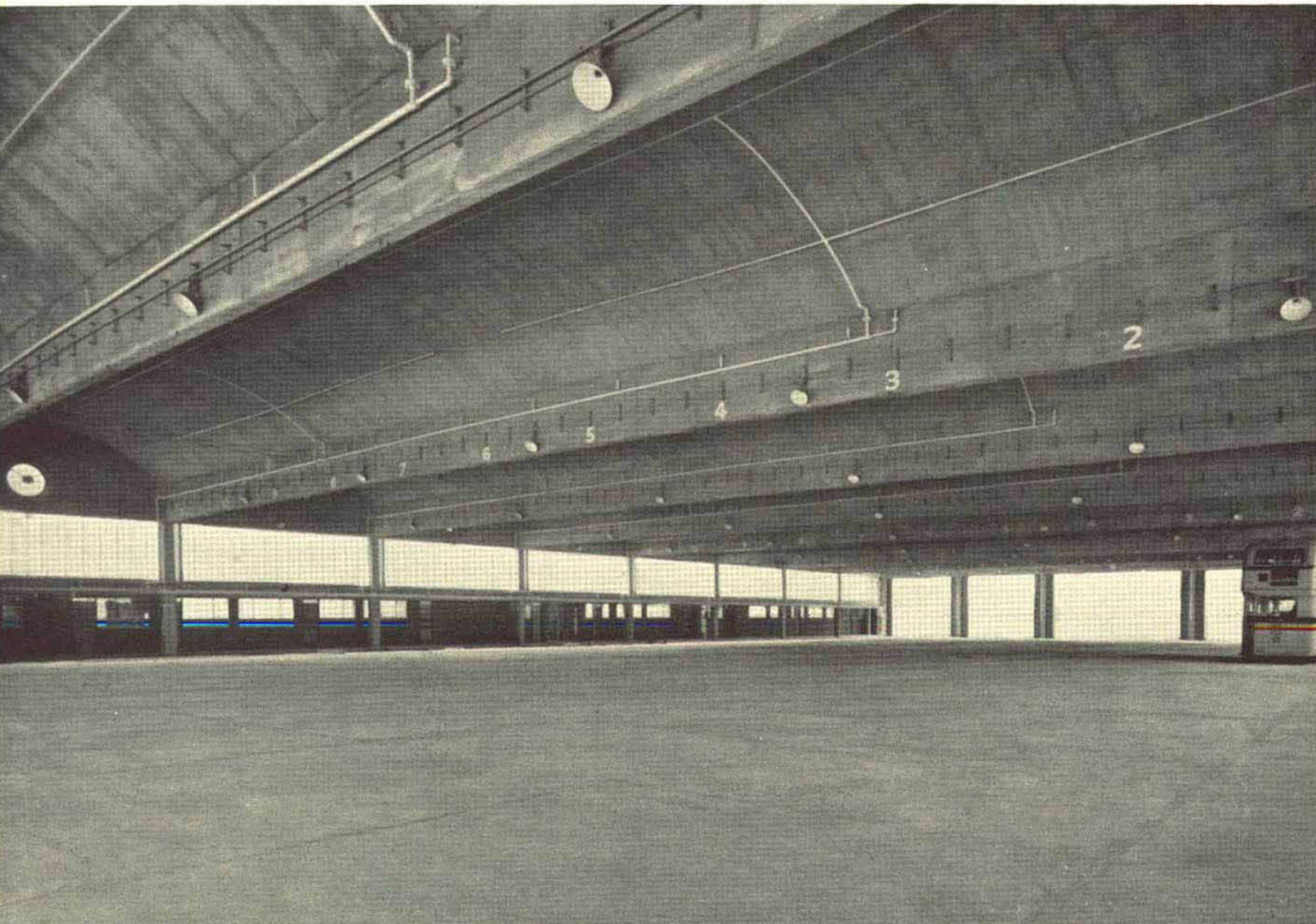
In 1948 plans for a new building were finally approved and the work put in hand. The scheme as a whole is on a grand scale. In addition to two large new garages with wash-building and maintenance workshops, it includes an office block, canteen and recreation rooms and an assembly hall. On the 24-acre site there are also to be football and cricket grounds, tennis courts, a bowling green, a children's play corner, and space for two or three houses for members of the staff.

One of the garages and the narrow office block adjoining it are so far completed—the garage as a concrete-framed, prestressed shell-roofed building. Its walls are brick-faced, and a continuous strip of window runs the length of one side, the vertical glazing bars contrasting with the horizontal lines of the boxing concrete frame.

The fuelling station is at this side of the

Top: The entrance end of the new bus garage. The cantilevered canopy of untreated concrete that runs the width of the opening is a sharp contrast to the soft curves of the small cantilevered shell-concrete hood over the petrol pumps on the right. Bottom: An interior view of the garage that emphasizes the great expanse of clear space obtained by shell roofing with prestressed edge beams.

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building, the pumps sheltered by an undulating shell concrete canopy cantilevered from the garage wall—a charming feature that echoes in miniature the curve of the roof. Along the other side of the building is the single-storey office block with windows giving on to the parking hall. The entrance to the garage, which takes up the full width of one end, has a canopy of untreated concrete with raked supporting walls.

The main hall provides 45,000 sq. ft. of completely uninterrupted floor space and accommodates 99 double decker trolley and motor buses; 300 ft. long and 150 ft. wide, it is roofed with nine thin concrete shells spanning the 150 ft. direction without any stiffeners or intermediate support—the longest span shells yet constructed.

The concrete of the shells is 2½ in. thick, increasing slightly to the valleys and ends; the chord width is 33 ft. and the rise from springing to crown is 6 ft. 9⅝ in. All intermediate edge beams are 10 in. wide and 5 ft. 6 in. deep; end beams are slightly larger and have an upstand.

The edge beams were prestressed on the Magnel-Blaton system with three parabolic cables, the lower of 56 wires and the two upper of 48 wires each; the ducts were formed with extractable rubber cores. The wire used was 7 mm. (0.276 in.) in diameter; with an extension of 7¾ in. in the 150 ft. length, the compressive force exerted on the concrete amounted to 507.4 tons. A 15 per cent. allowance was made for loss of prestress due to shrinkage and creep, bringing the final prestress to a figure of not less than 430 tons. To reduce the effect of shrinkage, these beams were cast in three sections—the centre first, and then the two ends. Though they were completed before the shells were constructed, it was not until the roof concrete had reached a specified strength that the beams were prestressed.

The beams, and all the remaining concrete with the exception of the shells, were compacted by vibration, with vibrators clamped on the formwork. The concrete of the shells was placed by pressure spray in order to overcome the difficulties of hand compaction. This concrete had a specified 28-day cube strength of 4,000 lb. per sq. in. and the pressure spraying gave a fine dense texture with a minimum of voids. The treatment of the formwork, to prevent adhesion of the concrete, appeared at first sight a considerable problem. Shutter grease was used on the first shell but was not satisfactory so subsequent shells were cast against completely untreated forms and striking was done without difficulty. Externally the roof is finished with bituminized felt.

A concrete-framed bus-washing building is also completed and a large workshop building with prestressed concrete northlight shell roofs is now under construction.

The decision to build the garage in concrete was taken originally as a measure of steel economy—it was in fact insisted upon to some extent by the Ministry of Transport—and the decision to use prestressing effected still further economies in both steel and concrete as compared with ordinary reinforced concrete shell construction.

Architects for the new garage and works are Jackson and Greenen, F/A.R.I.B.A., of Bournemouth; consulting engineers are R. Travers Morgan and Partners. James Drewitt and Son Limited, of Bournemouth, are main contractors, with the Vibrated Concrete Construction Company Limited as contractors for the prestressed work.

Placing the concrete of the roof by means of a pressure spray. It was later given a covering of bituminized felt.

A boldly cantilevered canopy

of concrete shells shades the baseball stadium at Cartagena

CARTAGENA, richest and most coveted of the golden cities of the New World, was a glittering beacon to the Elizabethan adventurers. They cared little enough for its fine buildings and the riches of its Spanish culture—so little that they sacked and looted the place when the chance came—but its wealth in gold and silver, emeralds and pearls, and no less its fortified position on the Caribbean coast, were a challenge that Drake, among others, found irresistible. Imagination paints Cartagena as a strange and splendid city between the mountains and the sea, shadowed by the Inquisition but all agleam with sixteenth-century drama.

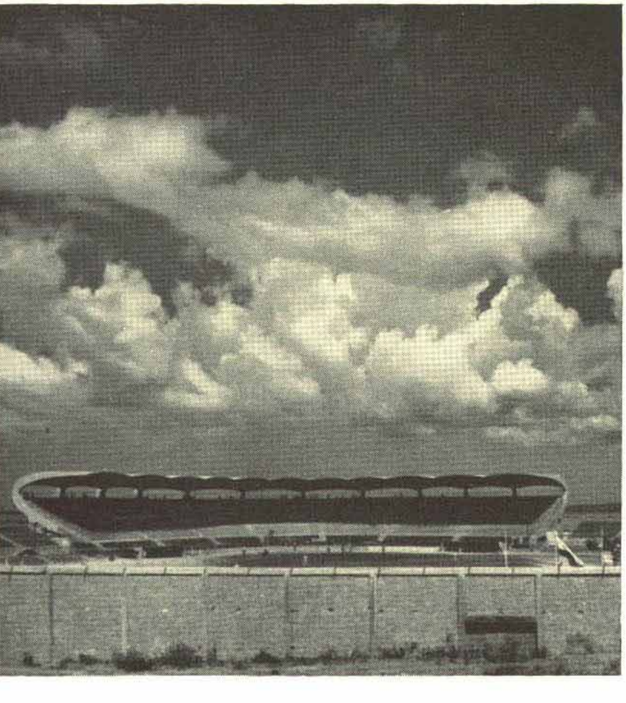
From this to a baseball match seems a far cry. But Cartagena has a new building to-day that equals in boldness and brilliance anything in its bold and brilliant past, and this new building is a baseball stadium.

The stadium, designed and executed by a team of Colombian architects and engineers, shows that though Colombia may turn to the United States for many things it still takes its artistic inspiration from Spain. The bold sweep of this cantilevered canopy of $1\frac{1}{2}$ in. thick concrete shells has a kinship with the daring imagination of a Torroja.

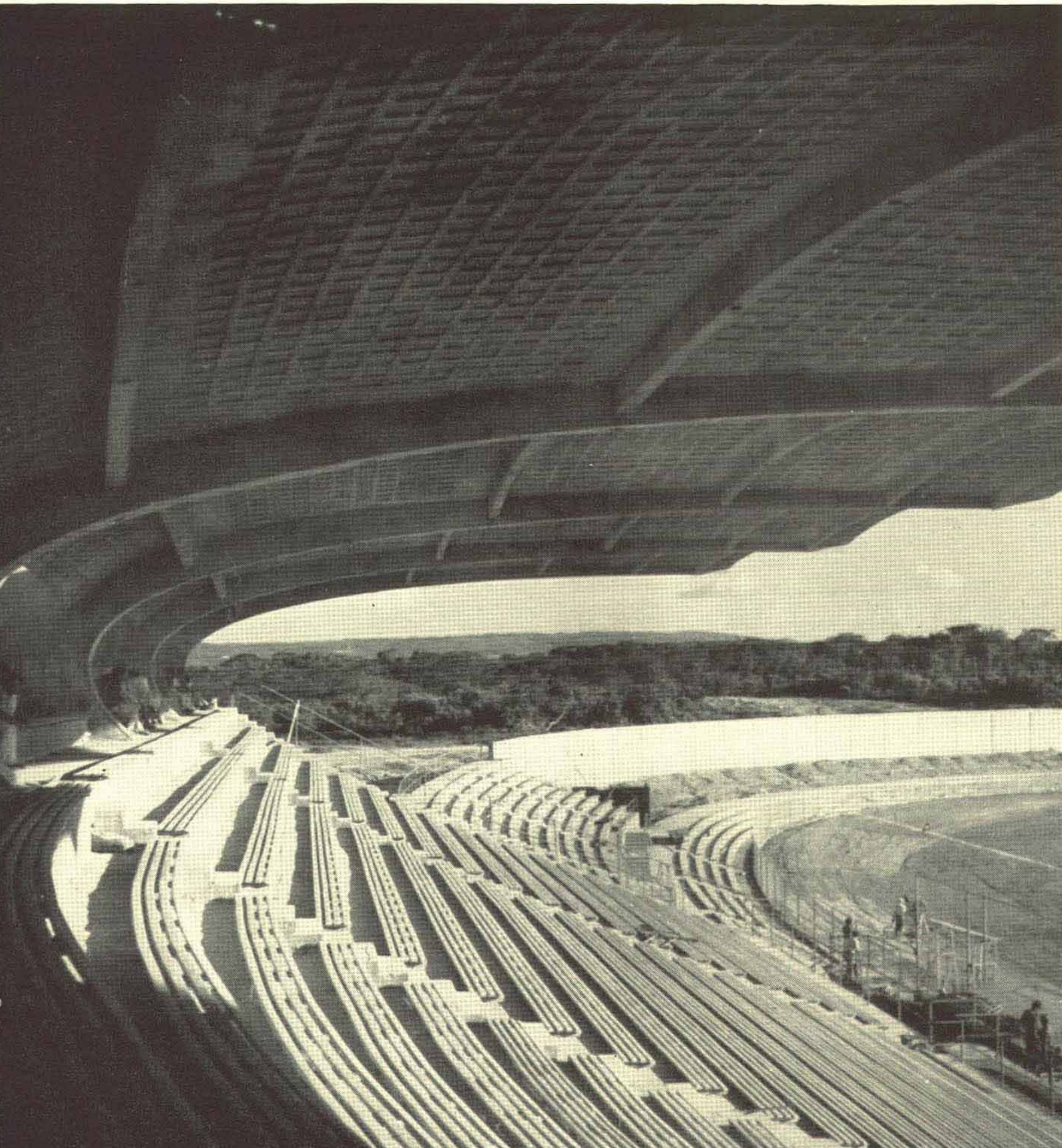
The entire building was constructed in the incredibly short time of 160 days, from first site preparation to playing of the first game. In 1946 Cartagena had been chosen as host city for the Amateur Baseball championships to be held the following year, and had no sports ground capable of holding the expected crowds. Hence the speed with which the work was accomplished—and how good to see, in what was essentially a "rush job," such imagination and such thought for the long-term result.

The work was carried out under the direction of the Department of National Building of the Ministry of Public Works. Four architects, Gabriel Solano, Jorge Gaitan, Alvara Ortega and Edgar Burbano were responsible for the design, and four engineers, Guillermo Gonsalez, Alfonso Majia, Mario Barahona and Julio Noel Montenegro, for the construction.

The stadium has the shape peculiar to baseball grounds—a rounded triangle—with seats for



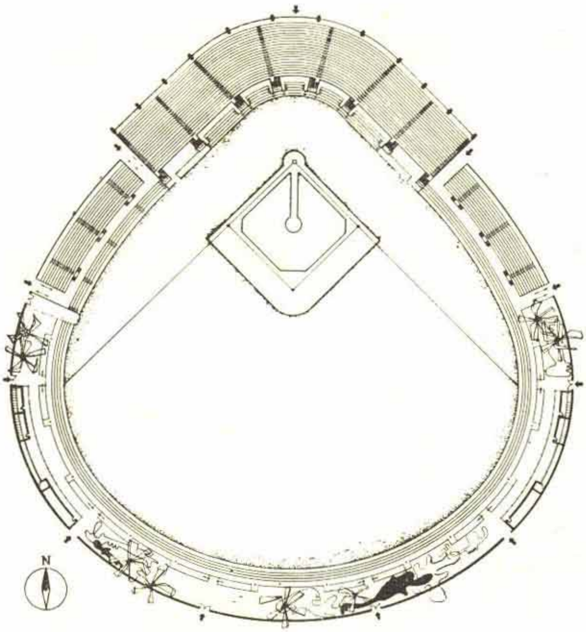
The stadium with its sweeping canopy of cantilevered shells.



18,000 spectators on the sides nearest the apex. The covered portion is at the apex itself, canopied with seven thin concrete shells, three of them tapering in plan.

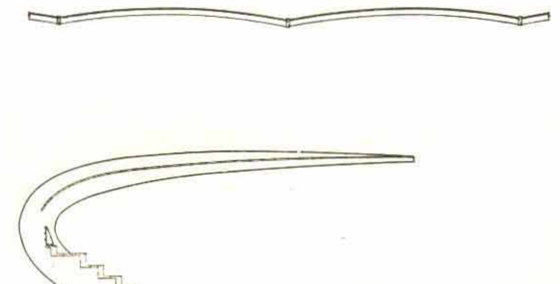
In section, the reinforced concrete ribs that carry the whole structure of tiers and roof in one bold curve are shaped like a flattened 'C'. The seats, of Z-shaped beams spanning the 35 ft. from rib to rib, are carried on the inside of the 'C's' lower arm. The top arm of the 'C' forms the edge beam to the shells, sweeping forward in a 60 ft. cantilever. Each rib—each 'C'—is carried on two columns, one at the front, the open end, the other some two-thirds back. The shells, spanning between these curved ribs, are thus curved in two directions, a flattened arch from rib to rib and a long sweeping curve from front to back.

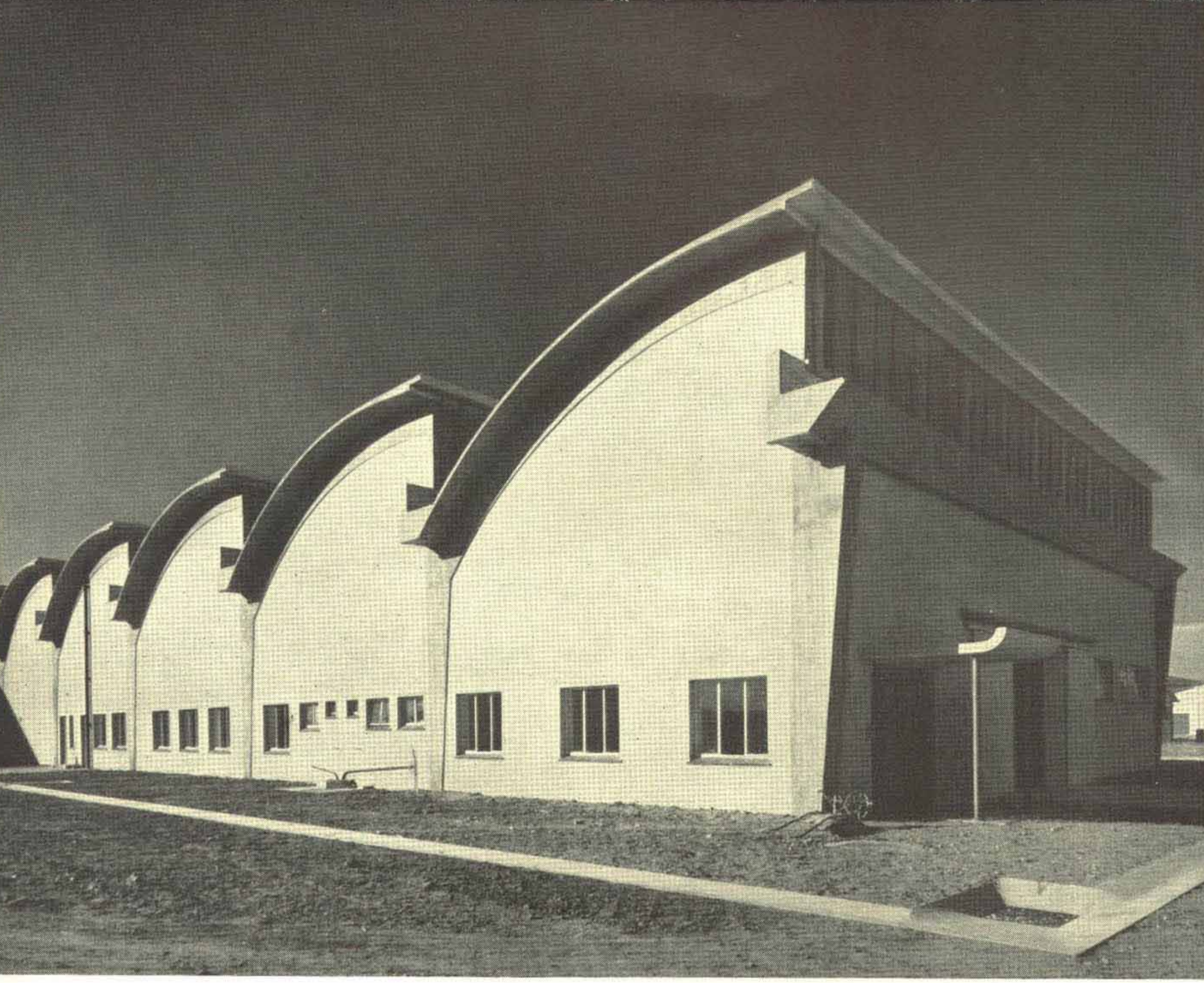
The stadium, on the low, steamy shores of the Caribbean, has its full share of difficult atmospheric conditions to withstand, but it is confidently expected that the carefully designed and high quality concrete used throughout the building will continue to be equal to all assaults from the warm, damp salt air—as it has been for the past five years.



Above: Plan of the ground, with the canopied grandstand at the apex. Below: Cross section through the covered stand, showing the profile of ribs, and section through shells spanning from rib to rib.

Opposite and below: Two views of the daring cantilever of $1\frac{1}{2}$ in. thick concrete that shelters the grandstand seats.





Above and opposite: A wire drawing and fencing factory where shells are of the standard design of 30 ft. between glazing and 60 ft. between supporting columns. The factory is laid out in two wings forming a right angle. The detailing is simple and attractive: the thin line of the overhanging shell thrown into sharp relief by the intense African sun and shadow; the outline of the tapered columns projecting slightly beyond the plain end walls, and the untreated concrete with its regular board marks contrasting with the rendered walls.

Left: Interior of the factory. A simple paint finish leaves the narrow, regular board marks clearly visible. Owner: Premier Gate, Fence and Wire Company Limited.
Architects: Andrews and Niegeman.

SHELL ROOFED FACTORIES IN

SOUTH AFRICA

IN SOUTH AFRICA shell roof construction was already being adopted with enthusiasm during the war and in the last fifteen years a considerable number of shell-roofed buildings have gone up.

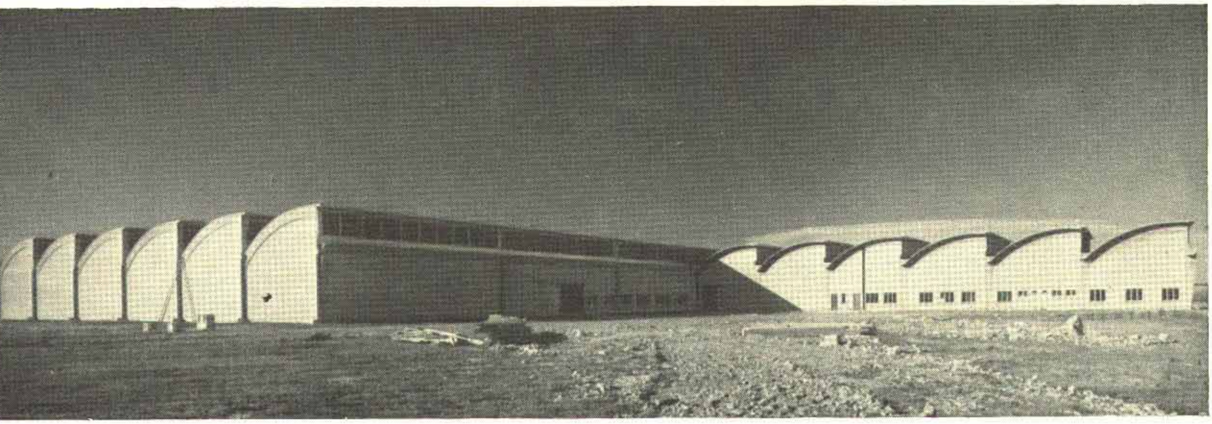
South Africa's first shell buildings had the now almost conventional top lighting, but owing to the greater height of the sun in South Africa, it was found that this was not a really suitable design for the country and later buildings have been erected with south-light shell roofs, of a type known as " D " shells. Some of the most recent are illustrated here.

These shell buildings, most of which are in Cape Town and Port Elizabeth, are similar in their basic design elements, though differing in size, layout and general planning. Dimensions were standardized to a great extent, so that formwork could be repeatedly re-used and construction costs reduced. According to factory regulations in South Africa no workers may be more than 30 ft. from a source of natural light, and to comply with this the majority of the "D" shells are 30 ft. wide between glazing. Columns in the other direction are generally at 60 ft. centres. Timber formwork was used in most cases and no attempt has been made to hide the board marks. The narrow regular ridging, so far from being a disadvantage, makes a definite and pleasant pattern on the concrete, and is finished with a simple wash in white or cream.

All the roofs are covered with a waterproof membrane of aluminized malthoid, a bituminized covering impregnated with aluminium powder, which reflects light through the glazing and also throws off the heat.

Window posts, which are arranged always to coincide with a glazing bar, are circular in section and are formed with 6 in. diameter asbestos cement pipes used as permanent formwork. Patent glazing is used in the majority of cases, with T-section bars spaced at 2 ft. 0½ in. centres. In many of the buildings the top edge of the glazing is kept at 6 in. below the soffit of the shell to provide permanent ventilation ; the opening is protected from the weather by an overhanging hood.

These factories were designed by the Chubb Reinforced Concrete Company S.A. Limited in collaboration with Chisarc and Shell "D" Limited, for whom H. G. Cousins, B.SC., M.I.C.E., M.I.Struct.E., acted as consulting engineer.



SHELL ROOFED FACTORIES
IN SOUTH AFRICA:
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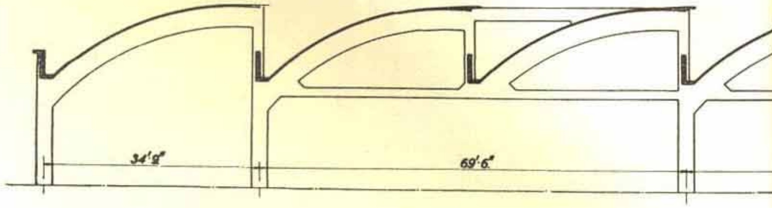
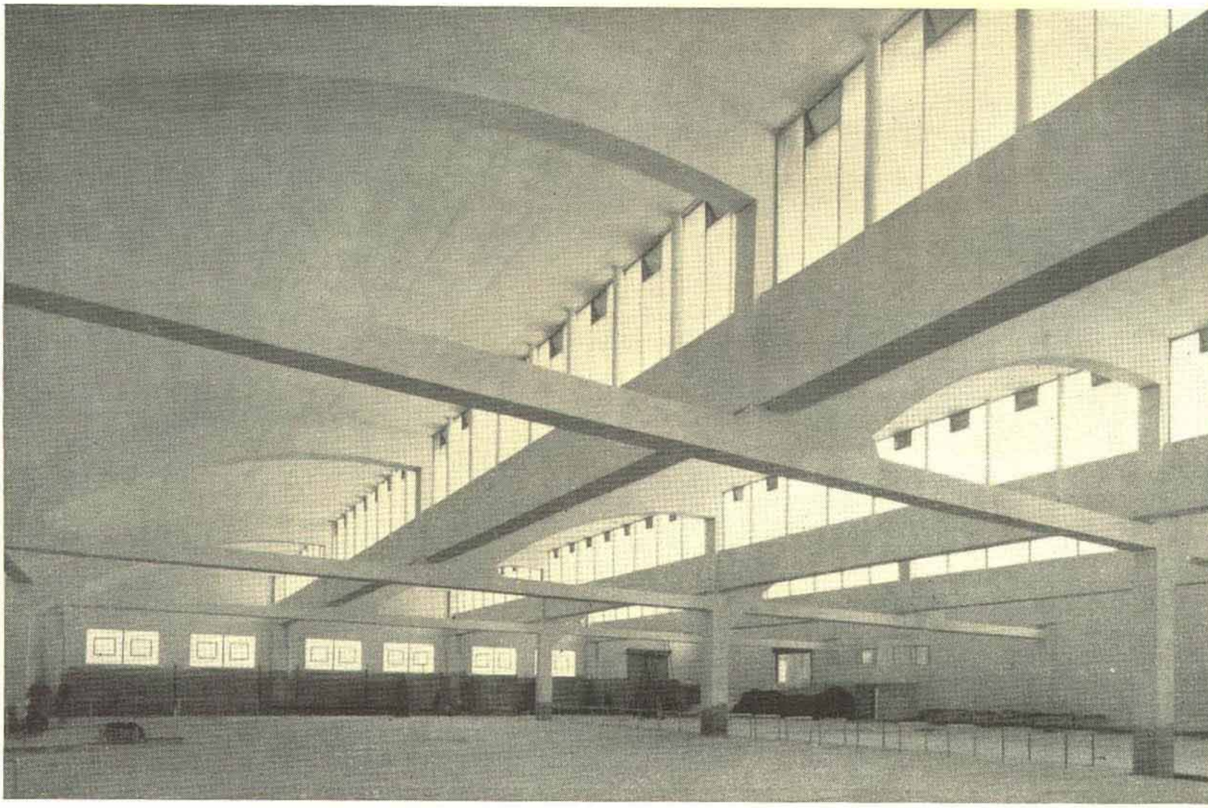
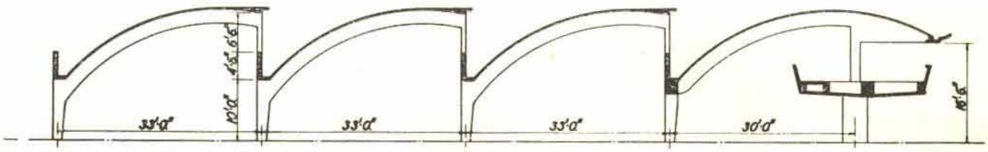
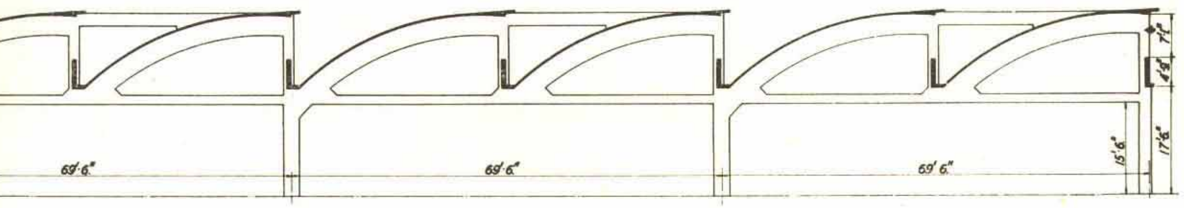




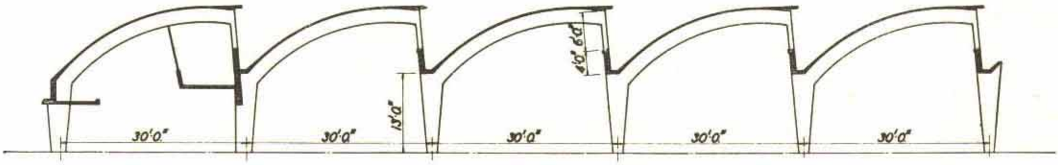


SECTION A.A

In a large garage building a mezzanine floor was required in one of the end bays. It was constructed as a balanced cantilever from two columns of increased width, and the shell carried over to cover it. The columns rising to the roof are hinged at mezzanine level.
Owner : Delville Garage.
Architects : Andrews and Niegeman.



Above and opposite : A workshop for the repair of motor vehicles. Here the standard pattern is varied. The owner wished to obtain extra large clear working areas and accordingly alternate rows of columns have been eliminated, giving a clear span of 69 ft. 6 in. In order to provide sufficient stiffness across the double span the ribs of the two adjoining shells have been incorporated in a concrete lattice beam by introducing a member joining the apexes of the two ribs and a tie beam at the top of the columns.
Owner : Atkinsons Motors Limited.
Architect : L. L. Small.



In one bay of a factory for the manufacture of ladies' underwear a mezzanine floor had to be provided without introducing additional columns. The valley beam was continued downwards and the floor, which overhangs an open well, was constructed as a projection from it. The outer edge of the floor is carried by a parapet beam hung from the underside of the ribs by means of ties.
Owner : Symingtons Limited.
Architects : Andrews and Niegeman.

A large factory manufacturing cardboard containers where the newest building effectively combines shell roofing with an end bay in reinforced concrete frame construction.
Owner : Mono Containers Limited.
Architects : H. L. Roberts and Partners.

The 'call stand' at Southampton

is a shell roofed building where dockers assemble to be assigned their day's work

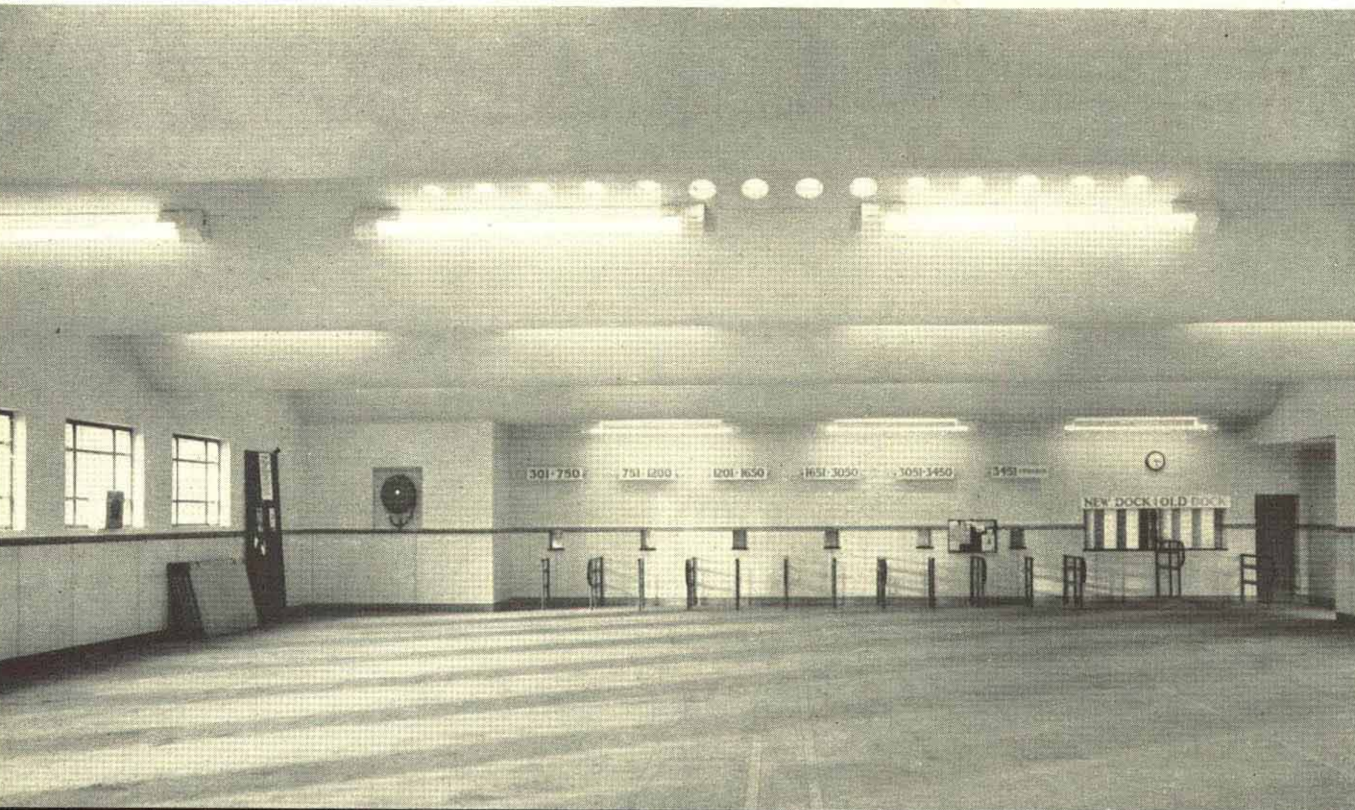
THE "CALL STAND" built at Southampton Docks for the National Dock Labour Board is the first of a number of such call stands now being erected in almost every port in England, Scotland and Wales.

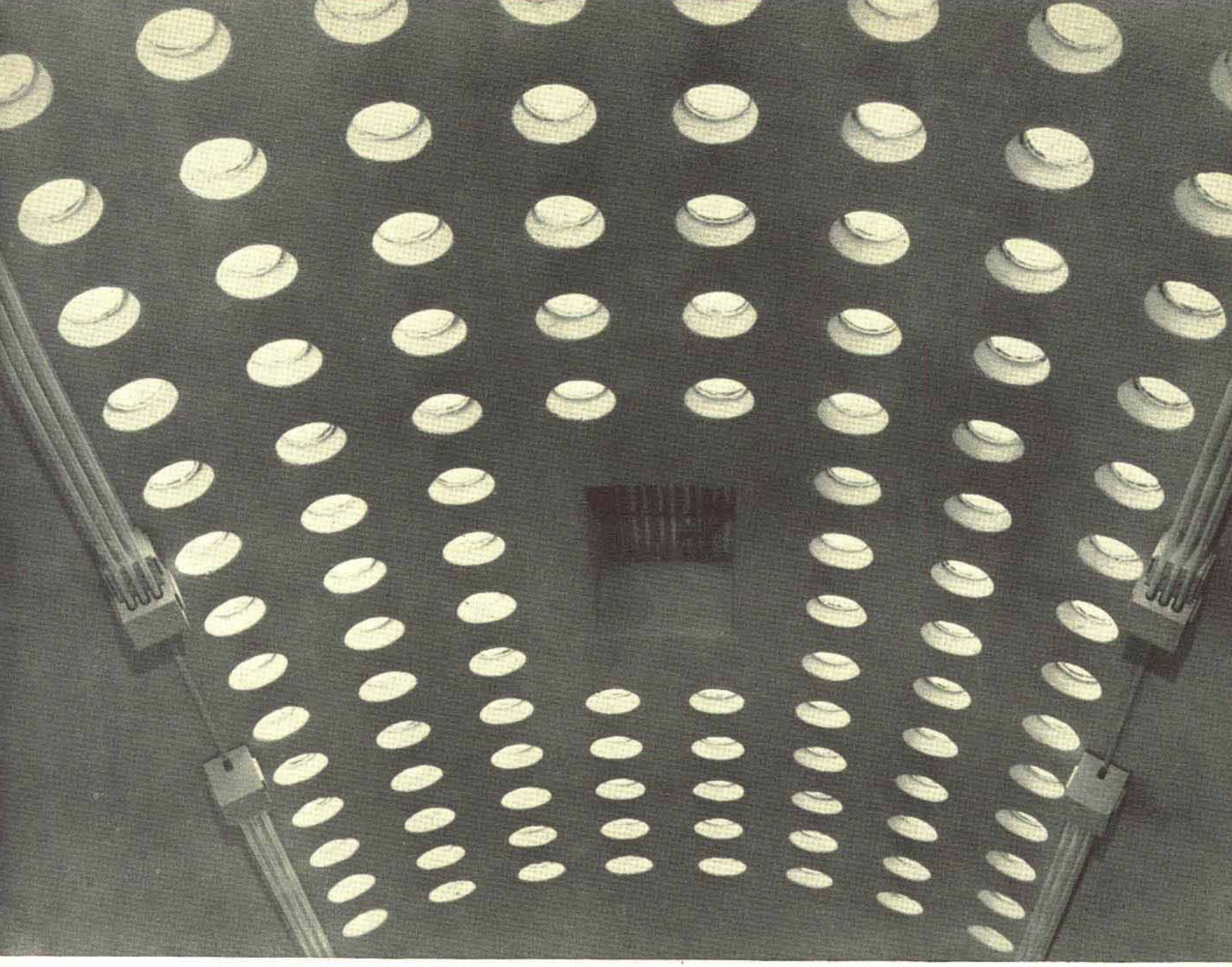
The building as a whole consists of the large hall, 100 ft. long by 57 ft. wide, which is the call stand proper, and a two-storey section containing offices. Below the offices there is a shelter furnished with tables and chairs, where the dockers can wait between "calls."

It is the main hall, where the dockers assemble to be directed to their jobs, that has a barrel vault roof.

There are five barrels, 20 ft. wide and 52 ft. long, carried on load-bearing brick walls. The

Interior of the main hall of the "call stand," a light airy room where the dockers line up to be allocated work at the Southampton Docks. The roof is pierced with numerous rooflights and the soffit sprayed with Vermiculite.





One barrel of the roof, showing the circular roof lights. Moulds forming these apertures in the concrete were held to the metal formwork by means of two magnets placed in each corner of a square centre hole in the mould. This method is being patented by the contractors.

concrete has a minimum thickness of $2\frac{1}{2}$ in. and the barrels are pierced at the crown with a quantity of 9 in. diameter lights arranged at 1 ft. 6 in. centres in both directions.

The construction of these roof lights appeared at first sight a difficult problem, but it was ultimately solved with a simplicity that looks almost childish—once it has been thought of.

Circular precast concrete moulds were used for forming the apertures and the difficulty was to find a means of fixing them to the curved steel formwork of the shell. The solution evolved (and patented) by the reinforced concrete contractors, F. Bradford and Company Limited, consisted of casting the moulds with a square hole at the centre and placing magnets in opposite corners of the hole. It was found that the attraction between the magnets and the steel formwork was sufficient to hold the moulds in place, even on the sloping sides of the shell.

These roof lenses give a very pleasant, even light inside the hall which is supplemented by windows in the side walls. The underside of the roof is sprayed with Vermiculite.

The architect for the building was A. J. Seal, F.R.I.B.A., and the consulting engineer was C. V. Blumfield, B.Sc.(Eng.), A.M.I.C.E., M.I.Struct.E. The general contractors were Brazier and Son Limited.

MODERNIZATION IN THE MARINES

The new drill hall at the Royal Marines Depot, Deal, is a vast, light, shell-roofed building

THE ROYAL MARINES have planned extensive alterations and improvements at their Depot at Deal. The old barracks were built about a hundred years ago and are very characteristic of their period, simple, dignified—and supremely uncomfortable to live in. The new buildings are also to be very much of their period—with a touch of humanity, even of gaiety, to enliven their dignity and simplicity.

Alterations have been undertaken in order of urgency. The Marines Depot at Deal takes in a steady stream of young recruits whose contentment as individuals is of more concern to the authorities to-day than it was a hundred years ago. The first building to be reconstructed, therefore, was a new reception wing, with lecture and recreation rooms, and light, airy dormitories with modern equipment and comfortable beds. Next came the welfare block: the spacious dining hall to feed a thousand at one sitting, the kitchens, the recreation rooms with their pleasant decorations, and the N.A.A.F.I. 'Tavern,' all housed in an amply-windowed building with lawns and trees in front, standing at the south end of the wide parade ground.

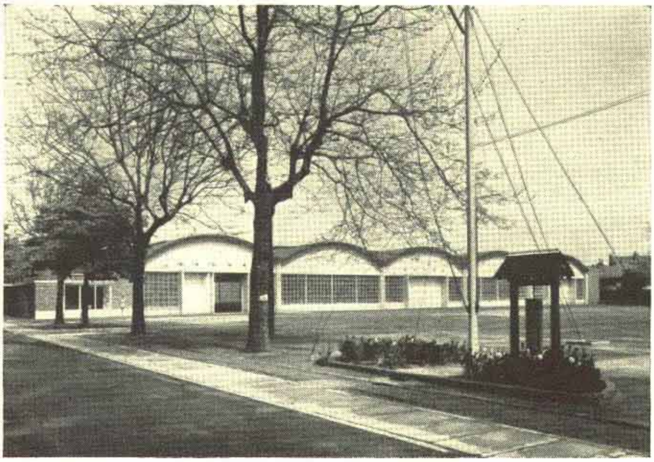
Facing this block, away at the opposite end, with the sun pouring on to its white façade, is the new drill hall, a bright boundary to the wide sunny square.

The old drill hall was a utilitarian shed to be hidden away behind the formal arcaded block. The new is the eye's focus, long and white, with clean smooth lines and curving copper roof.

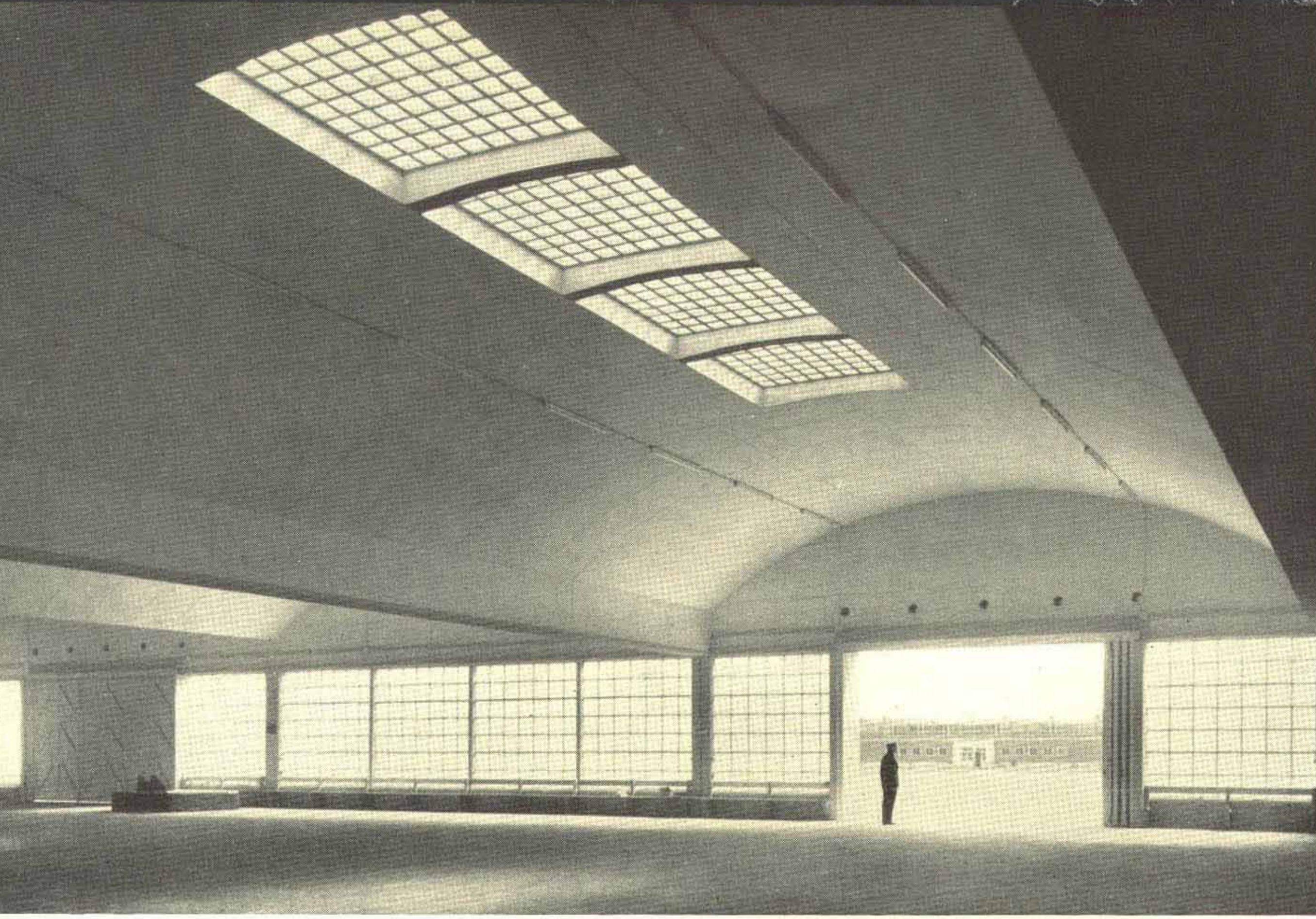
The new hall is larger than the old. It provides clear floor space 225 ft. long by 90 ft. 9 in. wide with no supporting columns whatever. The roof has five shells of thin concrete, each spanning 90 ft. 9 in. and 45 ft. wide; the walls are largely glass brick set in concrete frames; the floor is concrete.

There are two expansion joints in the length of the building, separating first and last shells from the three centre ones, and where these occur edge beams 3 ft. 6 in. deep are provided. Elsewhere the valley beam is simply a thickening of the shell from 3 in. (4 in. at the end columns) to 1 ft. 6 in., brought about by rounding the curve of the upper side, and carrying the soffit down to a point on the underside of the line of intersection. There is a clearance of 12 ft. 9 in. below the edge beams; elsewhere the height of the roof on the underside is 15 ft. 9 in. at the springing, with a rise of 11 ft. ¼ in. to the crown.

The concrete of both roof and edge beams was cast against insulating board, which was also used as permanent formwork for the inner side of the end spandrels. Externally these spandrels are cast with wide square-edged corrugations that make a clean-cut pattern of light and shade, broken by the round studs of ventilator shields above each door. Timber formwork was used for this patterning: 6 in. by 3 in. boards splayed at the edges, arranged to form evenly spaced grooves 5 in. wide and 3 in. deep. This concrete, and the strip below the windows, is finished with light stone-coloured 'Cementone.' Columns, door and window frames, and the soffit of the overhanging roof are left untreated. The roof itself is covered with copper sheeting and flashings are copper finished. Internally, the walls at each end up to window level are lined with light-coloured brick.



Left and below : The new drill hall which closes one end of the parade ground at the Royal Marines' barracks. Finished light stone colour, with primrose paint and a copper roof, its effect is bright and pleasant. The grooves in the gable ends were obtained by casting the concrete against ribbed timber formwork.



Interior of the drill hall. Glass brick, used as rooflights in each shell, and as windows the whole length of the building make the interior very light. Seats run the length of each side and rifle racks across the end.

The doors, which fold back concertina fashion, are painted primrose yellow, as are the down pipes which occur in front of each supporting column. It was originally intended that these pipes should be copper, like the roof, but owing to delays in obtaining the material the plans were changed. In appearance the building has not lost by it.

The greater part of the wall on each side is formed by 'Luxfer' concrete windows; the same type of glazing was used for the rooflights, and the interior, in spite of its great size, is superbly light.

For the time being the modernization of the Deal Depot has stopped with the completion of the drill shed, which, started at the end of October 1950, was ready for use by the beginning of September 1951. At present, recruits after two weeks in the comfort of the new dormitory block, are moved to the old buildings, with all their lack of convenience. But as soon as funds can be allocated for the purpose, these buildings are to be demolished and others on the new model, built round three sides of a green, will take their place. Tennis courts, on what is now waste ground, will be final evidence of the new regard for the welfare of the young recruit.

The architects for all the new work at Deal Barracks are Julian Leathart, Son and Tingay. Engineers for the shell construction were Barrel Vault Roofs (Designs) Limited. Contractors were Gilbert-Ash Limited.

May and Baker have planned a new factory for their Dagenham works. It will be roofed with

THREE SQUARE-BASED SHELL DOMES

"CONCRETE QUARTERLY" does not usually describe buildings unless they are at least well under way. This time, however, it is departing from custom because here is a building that deserves a place in this number devoted to shell structures, even though its construction is delayed for lack of a licence.

This is the new 'pharmaceutical preparation and packing' building for May and Baker, the manufacturing chemists, whose 'Building 21' was described in *Concrete Quarterly 5.* The same architect, Edward D. Mills, F.R.I.B.A., designed both buildings—as well as the delightful canteen for the same firm, which was one of the first shell buildings to be constructed in this country after the war, and is still one of the most attractive.

The new building is to be considerably larger than either of these two earlier ones. It will consist of a central packing hall 224 ft. long by 64 ft. wide, reaching from ground to roof and surrounded on all sides by offices and preparation rooms on two floors.

The raw materials from the nearby factory are to enter on the ground floor where, in a series of separate dispensaries, they will go through the processes that transform them into tablets, emulsions and injections. On the first floor are ampoule preparation and filling rooms, sterilizing rooms, testing laboratories and finishing rooms, and from here the products are conveyed back to the ground floor to be bottled and sealed at long tables running transversely across the central hall.

Visitors, who come in large numbers from all parts of the world to visit the May and Baker factory, are to be catered for in the new building on a scale rarely before attempted. The ceremonial entrance at the east end leads into a reception hall from which visitors are taken, by a double-branching staircase, to the gallery which surrounds the packing hall at first floor level. From this gallery they can observe, without interrupting, the work being done in the packing hall and, through internal windows, watch also the processes carried on in the first-floor rooms. Opposite sides of the gallery are to be linked by two prestressed concrete bridges, 48 ft. in span.

The factory is to be built with a light steel frame, with basement, ground- and first-floors and roof of reinforced concrete slabs. External walls will consist for the most part of continuous windows alternating with panels of built-up cork faced with aluminium that will be finished in blue-grey stove-enamel. The only exception to this treatment is the north-east corner, where the more domestic character of smaller rooms to be used as offices is expressed by individual square windows boxed in concrete frames and set in brick panel infilling. Everywhere floors are of considerable depth, to accommodate all the services; in this corner suspended ceilings still further increase the inter-floor depth, to give pleasant proportions to the small rooms.

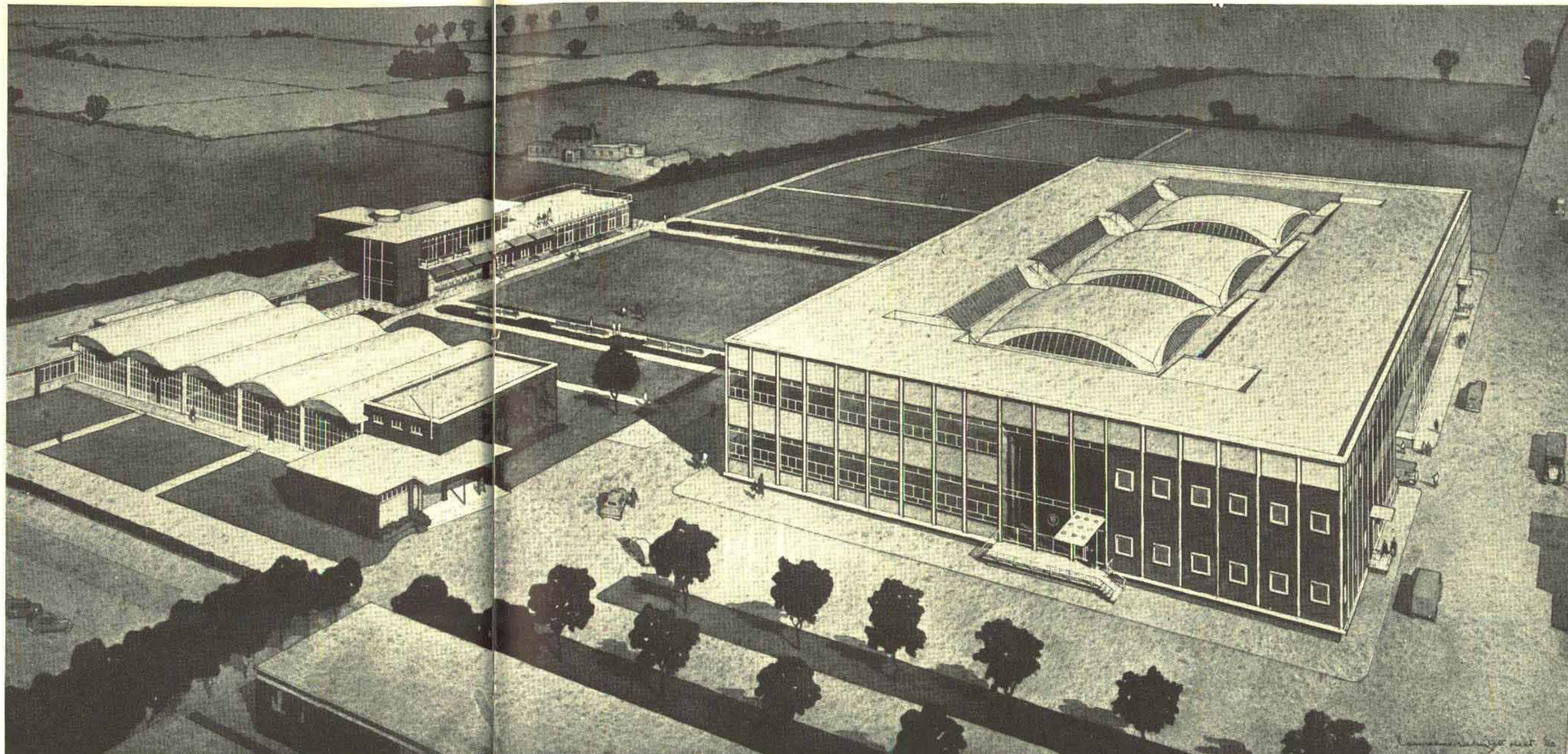
The most interesting structural feature of the building is the roof of the packing hall, which is formed of three large, square-based shell concrete domes, separated from one another and from the remainder of the building by an 8 ft. wide concrete walkway. The base measurements of each dome are 64 ft. by 48 ft. and the glazed spandrel sides will be sloping, to increase the in-flow of daylight. These spandrel sides are in the form of reinforced concrete bowstring girders, the upper member following the curve of the dome; the lower, horizontal, member will be cast in one with the walkway which acts as a stiffener to the shell.

The domes are carried at each corner on a short length of steel lattice beam cantilevered out from the structural frame, so that they float above the hall without visible support.

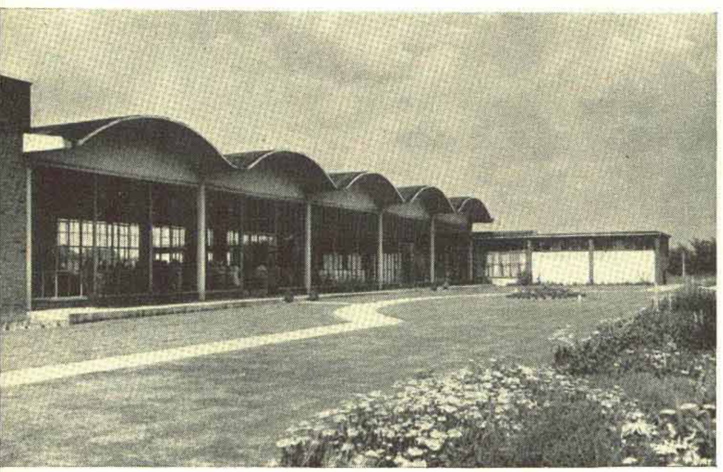
Staircases throughout the building are to be reinforced concrete, and will be encased in reinforced concrete walls which will act as stiffeners to the structure.

In view of the processes within the building a comprehensive air conditioning and dust extraction system is to be installed, and heating will be by hot air, except for the main packing hall and west block, which will be heated by radiant heating coils in the floor.

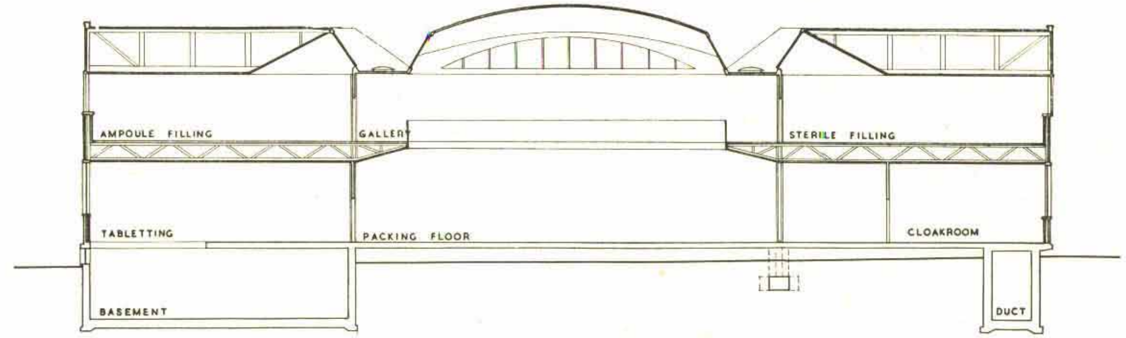
Consulting engineers for the new building are Ove Arup and Partners and Allen Fairhead and Sons Limited have been appointed general contractors.



The pharmaceutical preparation and packing building planned for May and Baker is here seen in relation to the rest of the site, with the existing canteen on the left. This architect's drawing shows the design of the three domes of the roof with their sloping spandrels, and the cantilevered beams that support them at each corner.



Left: The shell-roofed canteen erected for May and Baker in 1945 is as attractive as ever. The architect was Edward D. Mills, F.R.I.B.A., and the engineers Barrel Vault Roofs (Designs) Limited.



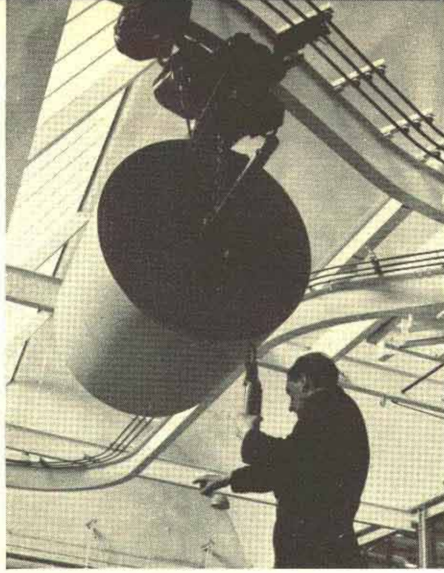
Cross section through the proposed factory, showing the composite construction of light steel framework and shell concrete domes. The footbridges connecting the galleries which surround the main hall at first floor level are of prestressed concrete. The basement, floors, and flat roof are of reinforced concrete.

Cement made the factory,

the factory made the bags,

the bags hold the cement . . .

and the factory has a roof of



LONG-SPAN PRESTRESSED SHELLS

THE BOWATER PAPER Corporation's Mersey Paper Mills lie close to the Manchester Ship Canal, where it runs along the south bank of the Mersey estuary. Wood pulp, in partly dried baled form, and other necessary raw materials, come by water to the mills, there to be converted, first to ' slush ' pulp, and finally to paper.

Bowaters now have a twenty-acre extension to their original site, where they have built a factory for the manufacture of ' multiwall ' paper sacks, of the type familiar as cement bags. The new works consist of the ' tuber machine room ' where the sacks are manufactured on machines of an astonishing ingenuity that run the full length of the room, the reel store where the reels of paper are kept and, at the end nearest the canal, the finished sack store. A small flat-roofed section down one side of the machine room contains administration offices on two floors.

The whole building is ultimately to cover a large rectangle with the reel store across one end of the machine room and the finished sack store across the other. At present just over half the building is completed : the long strip that is the machine room and sack store, now only half its ultimate width, with the completed reel store making the foot of an ' L ' at one end.

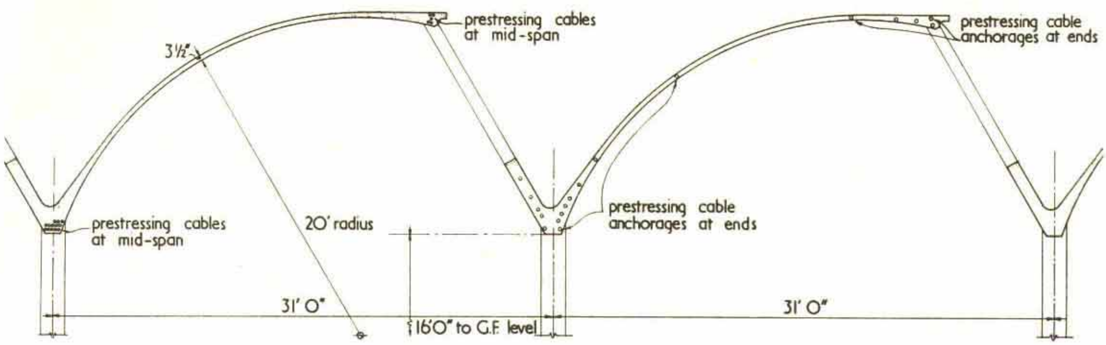
The machine room and sack store section has a total length of 496 ft. divided into sixteen 31 ft. wide bays roofed with northlight shells. Each shell spans the width of the building—100 ft.

These are thought to be the largest northlight shells so far designed. To enable them to span the 100 ft. width without intermediate support, they were prestressed with eighteen 12-wire cables distributed between the lower valley and edge beam and the upper edge of the shell. The cables in the lower edge were curved up towards the end of the span, some going up into the edge beams, and others being spread into the shell. The cables in the top edge were also carried into the shell. A 100 ft. span free-standing edge beam prestressed with twenty cables takes the thrust from the northlight framing of the last barrel.

It is believed that this is the first time that prestressing cables have been carried through the shell. The spreading of the cables enabled a much greater degree of curvature to be obtained than is the case where the cables are confined to the beam and consequently a much larger proportion of the shear forces were absorbed, with a corresponding reduction in the shear reinforcement.

Plastic sheaths were used to protect the cables

Opposite : The interior of the tuber machine room, the northlight section of the factory where the 'multiwall' bags are made. This room is outstandingly light, and its decoration enhances the effect of brightness.



Cross sections through a northlight shell, showing the arrangement of the prestressing cables, which rise at the ends into the concrete of the shell itself. The left-hand section shows the position of the cables at mid-span, and the right-hand section shows this position at the anchorages.

during concreting and precast concrete templates were fixed at intervals to retain the cables in position. The Freyssinet system was used, and after tensioning the cables were grouted up with colloidal cement.

These shells are formed to a radius of 22 ft. 6 in., with a 9 ft. depth of glazing. The concrete has a minimum thickness of 3 in., increasing to 4 in. where the prestressing cables run through the shell.

In this section of the building the daylight obtained through the northlight roof is supplemented by tall windows up to edge-beam height in the whole length of the wall and the interior is strikingly light. The opposite wall is, of course, only temporary.

The internal finishes add to the brightness of the room and the cheerful working atmosphere. Roofs and all overhead fittings are sprayed with white Vermiculite and the columns are painted white above an aircraft-grey dado. Walls have the grey dado with pale primrose panels above. The metal window frames are pale primrose, while deep orange doors are set off by frames of peacock blue. Machinery is peacock blue, and piping has the various gay colours allotted to it by the British Standard colour code.

The reel store is divided into eight bays roofed with symmetrical barrels, each 25 ft. wide and spanning the 83 ft. width of the building. These shells are constructed to a radius of 18 ft. with a reverse curve of 2 ft. radius at the valleys. They are prestressed on the Freyssinet system with ten 12-wire cables arranged in the valley beams and spreading into the shell at the ends of the span. The shell concrete is 2½ in. thick, increasing to 4 in. at the ends to accommodate the prestressing cables.

Natural light is given by 3 ft. 6 in. square openings in the roof, glazed with wired rough cast glass, and although the area of glazing is only 7 per cent. of the floor area, it gives ample light for general purposes.

As in the tuber machine room, the interior of the shells is sprayed with white Vermiculite. In this section, which is only used for storage, decorations are omitted. Columns are as left by the formwork, and walls are fair-faced brick. Window frames, however, are the same pale primrose, and doors the same deep orange.

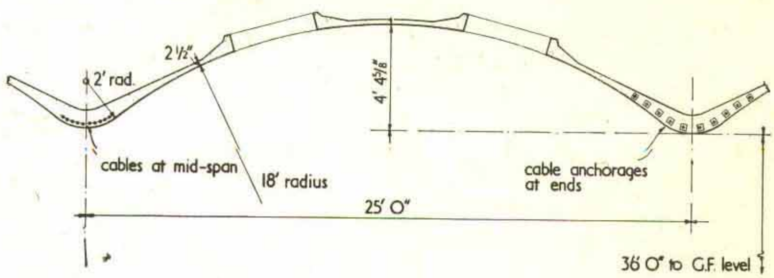
In both northlight and symmetrical barrels expansion joints were formed in the valleys, the joint extending about 16 ft. along the valley from the stiffening beams at each end. This method of arranging the expansion joints allows relaxation in the line of the stiffening beams but saves the necessity of providing extra edge beams along the length of the barrel.

Externally, the shells in both sections are insulated with 1½ inches of Vermiculite concrete covered with a waterproofing layer of bituminous compound on a hessian base.

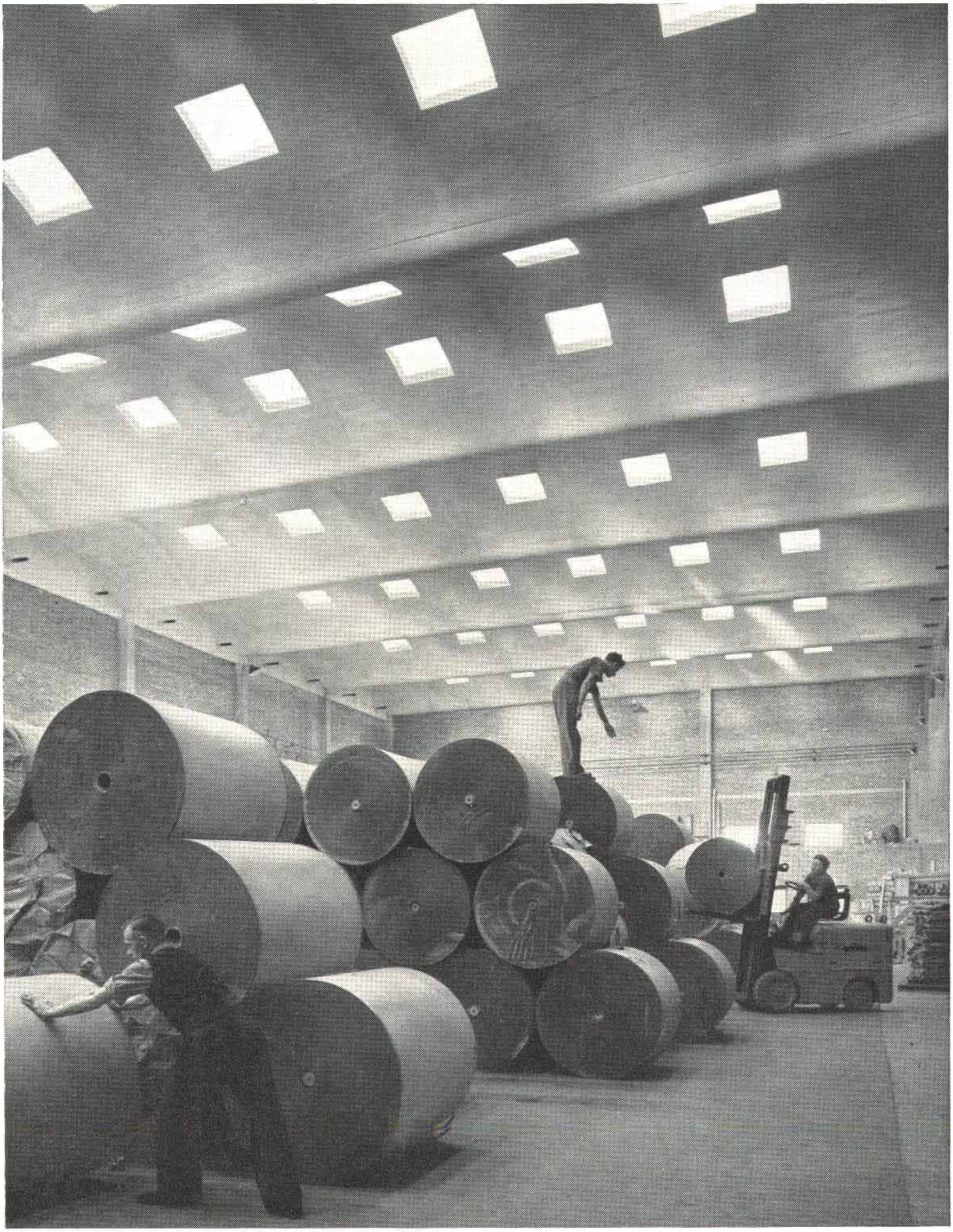
As the work was to be done during the winter special arrangements were made for concreting in cold weather. The aggregates and mixing water were heated, rapid-hardening cement was used and holed steam pipes were run along the underside of the formwork. By this means work proceeded without interruption from December until the summer. Care was taken to ensure that the concrete test cubes were cured under conditions identical to those of the work on the site.

The formwork used for the shells was designed by the contractors, Sir Alfred McAlpine and Sons Limited, who hold the patent. It was made up of sheet steel bent to the required curvature, with wedge-shaped stiffeners in the longitudinal direction.

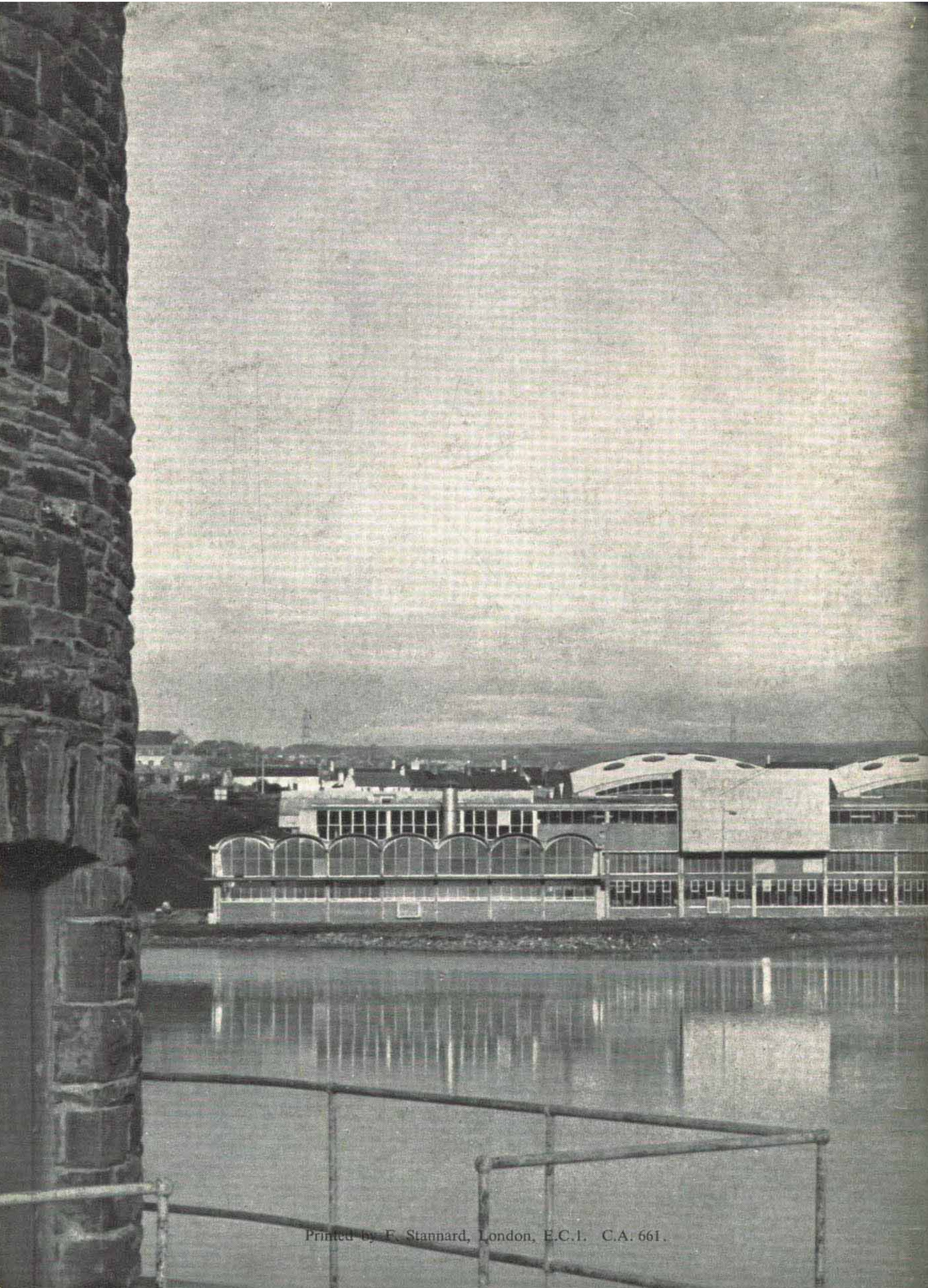
Architects for the scheme are Farmer and Dark, F/F.R.I.B.A. C. V. Blumfield, B.Sc.(Eng.), A.M.I.C.E., M.I.Struct.E., was the consulting engineer.



Cross section through a symmetrical shell showing the position of the prestressing cables: on the right at mid-span, on the left at the anchorages.



Interior of the reel store built across one end of the tuber machine room. This section of the building is roofed with symmetrical barrels pierced with square roof lights.



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