DREDGING AND MARSH RECLAMATION AT SOUTHAMPTON.

THE largest dredging scheme in the history of the Southampton Harbour Board, which has recently been completed six months ahead of schedule, has improved considerably the approaches for the many large ships now using the port. A secondary part of the work, of civil engineering interest, has been the reclamation of marshes on the west bank of Southampton Water, by pumping some of the dredged material through a pipeline to the site. Before the reclamation work was started, the main contractors, the Dredging and Construction Company, Limited, King's Lynn, commissioned Messrs. Soil Mechanics, Limited, 123, Victoria-street,

FIG. 1. RECLAMATION AREA, PIPELINE AND PUMPING DREDGER.

Fig. 2. PORT OF SOUTHAMPTON.

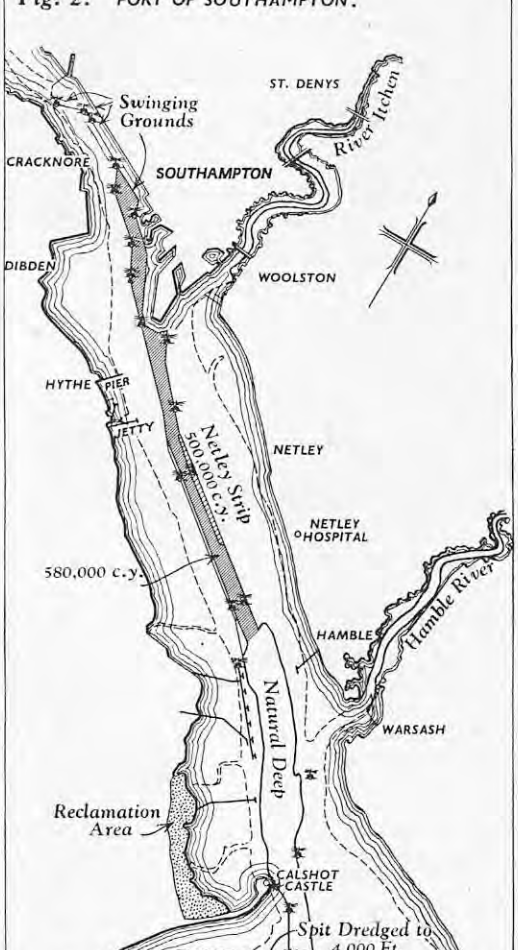


Fig. 3. BOREHOLE POSITIONS.

London, S.W.1, to investigate and report on the proposed method of reclamation, considering, in particular, the heightening of an existing bank which formed the seaward boundary of the site, and the depth of dredged material that could safely be deposited. The reclamation area is shown near the top of Fig. 1, herewith; Fig. 2 is a map of the port and also shows the site of the reclamation area. Radio-telephone control points were established at several points for communicating continuous tide-gauge readings to the dredgers, and for direct intelligence and overall control. The dredging contract was supervised on behalf of Harbour Board by Commander D. H. Macmillan, R.N.R., F.R.I.C.S., their hydrographic surveyor, and the reclamation was supervised by Mr. J. P. M. Pannell, M.B.E., M.I.C.E., M.I.Mech.E., the engineer to the Board.

From 1882, when the Harbour Board first obtained Parliamentary powers for deepening the waterways of the port and the approaches, until 1907, the main channels were dredged to a depth of 32 ft. M.L.W.S. (mean low water at Southampton) in order to accommodate larger ships which were being built for the Atlantic Service. The increasing draught of vessels meant that, between 1922 and 1927, continuous operations for widening and deepening were necessary, not only in the reaches above Fawley up to the docks (Fig. 2), but also in the natural channel below Calshot, down to the south-western extremity of the Brambles shoal. In 1931, the Southampton Harbour Board commenced the largest single dredging contract undertaken up to that date, involving the excavation of 2,750,000 cubic yards of material in order to widen the channel where possible to 1,000 ft. and to deepen the reaches below Calshot to 38 ft. M.L.W.S., so that, when the liner Queen Mary went into service, Southampton was ready to receive her with her 39-ft. load draught. The second World War deferred plans for further dredging, but after the war the Board decided on a programme for the rectification of the channels to Fawley reaches, the Calshot Spit and Western Approach, to facilitate the entry of the largest ships. Accordingly, in 1950, the Dredging and Construction Company were awarded a contract by the Board, the largest ever undertaken in the port, for major dredging works, entailing the removal of 3,500,000 cubic yards in three principal areas.

These three areas of virgin dredging are shown in Fig. 2, together with areas of maintenance dredging. At the first area, the western margins of the Western Approach channel, off the West Bramble light buoy, and up to the Bourne Gap light buoy in a direction of 041 deg./221 deg. (true), have been dredged away to a least depth of 38 ft. below port low-water datum (P.L.W.D.). This bold widening of the entrance to the reach was designed to give greater freedom for ships in turning inwards, and particularly for the 1,000-ft. liners using the port, and was based on research involving the plotting of the tracks of ships making this critical turn. It is understood that the benefit of this work has already been felt and favourably commented on by pilots and shipmasters. The quantity of material removed was 850,000 cubic yards, composed of clay and gravel from areas where practically no silting occurs, owing to the dominant westerly streams of the Solent. Above Calshot the maximum ebb tidal stream does not exceed 2¼ knots, but the stream in the Western Approach may attain velocities at spring tides of 3 knots. Thus, with strong W.S.W. gales, a heavy "fetch" develops, and it was therefore necessary to suspend work at this site from September, 1950, to April, 1951.

The second part of the work consisted in dredging away the eastern corner of the Calshot Spit to a curve of 4,000-ft. radius, in line with the straight edge to the first part of the dredging, to give an easy turn for large ships with moderate helm, and normally without engine assistance. The quantity involved was just under 1,500,000 cubic yards of a mixture of clay and gravel. Excavation was carried out from a depth of 8 ft. down to 38 ft. below P.L.W.D., but to ensure under-water stability an intermediate 50-ft. terrace or berm has been cut, with 1-in-3 slopes above and below it. The Queen Mary and Queen Elizabeth draw up to 40 ft., and may, due to hydraulic factors, increase their draught by another 2 ft. in shallow water. In the United Kingdom, only Southampton is required to provide sea channels for such depths, combined with the lengths of these ships. In addition to dredging the new Calshot curve, some slightly shoal areas of the adjacent channel and Calshot Reach have been re-dredged, where necessary, to the same depth of 38 ft. Very little accretion has occurred in the main channel below Calshot since dredging in 1934. The greatest width of the channel off the Spit has now been increased from 1,650 ft. to 2,500 ft.

The third virgin dredging area was in the natural "deep" between Calshot Castle and Fawley, which has depths of well over 42 ft. below P.L.W.D. Above Fawley Beacon and the new Esso oil refinery lie those reaches of the main channel which have hitherto required constant dredging and which extend, so far as the Board are concerned, to Cracknore, near the new docks. A heavy rectification on the east side, between the north-west Netley light buoy and shoal and the Cadland light buoy, has been made by dredging to a line 129 deg./309 deg. in alignment with the dominant tidal ebb scour. This has moved the axis of the channel about 250 ft. eastward and the eastern margin some 400 ft. into a submerged terrain not so liable to silting as the western margins, which were composed of silt and mud from the soft swampy foreshores lying between Fawley and Hythe and interspersed with run-off creeks. The material dredged in the Netley "strip" (shown in Fig. 2) consisted of peat and timber from prehistoric forests over clay and gravel, but dredging was not difficult. Some Roman pottery was also recovered. Elsewhere in the reaches above Fawley, silt and accreted gravel and shingle predominated, with some greensand and a few large boulders. The quantity of material removed in the reaches above Fawley was just over 500,000 cubic yards, half of which was from the Netley strip.

During the peak period of the work the vessels used were three large bucket dredgers; a "reclamation dredger" (i.e., the dredger shown in Fig. 1, which was, in effect, a pumping station for filling the reclamation area); ten self-propelled sea-going hoppers; seven dumb barges for conveying material to the reclamation dredger, and various tugs and ancillary craft. Up to 250 men were employed. About 2,000,000 cubic yards of material were pumped into the reclamation area, the remaining material being dumped at sea in authorised deposit areas off the Nab Tower and the Needles. The radio-telephone control points were established at Calshot, Hythe, and the Town Quay, Southampton. It was thus possible to communicate with any dredger by day or night via a land line to the control points and thence by radio-telephone. After dredging, soundings for the required levels were made by reference to visual tide gauges stationed at two-mile intervals, the means of the readings giving one-mile virtual intervals. Precomputed sextant arc graphs covering the entire area, depending on closely triangulated control and defining all positions on the contract drawings, were used for siting and controlling the dredgers and for final surveys. The contract allowed 20 months for the work, but, as already stated, it was completed six months earlier.

Following the completion of the dredging programme, the Board are planning a revision of the buoys, beacons and other navigational aids in the port area. A port control and information service, using radar and radio-telephony, is also being considered, with the object of providing full information to shipping authorities for the safe and speedy handling of vessels in the port.

RECLAMATION OF MARSHES AT SOUTHAMPTON.

FIG. 4. PIPELINE JETTY FROM DREDGER TO RECLAMATION AREA.

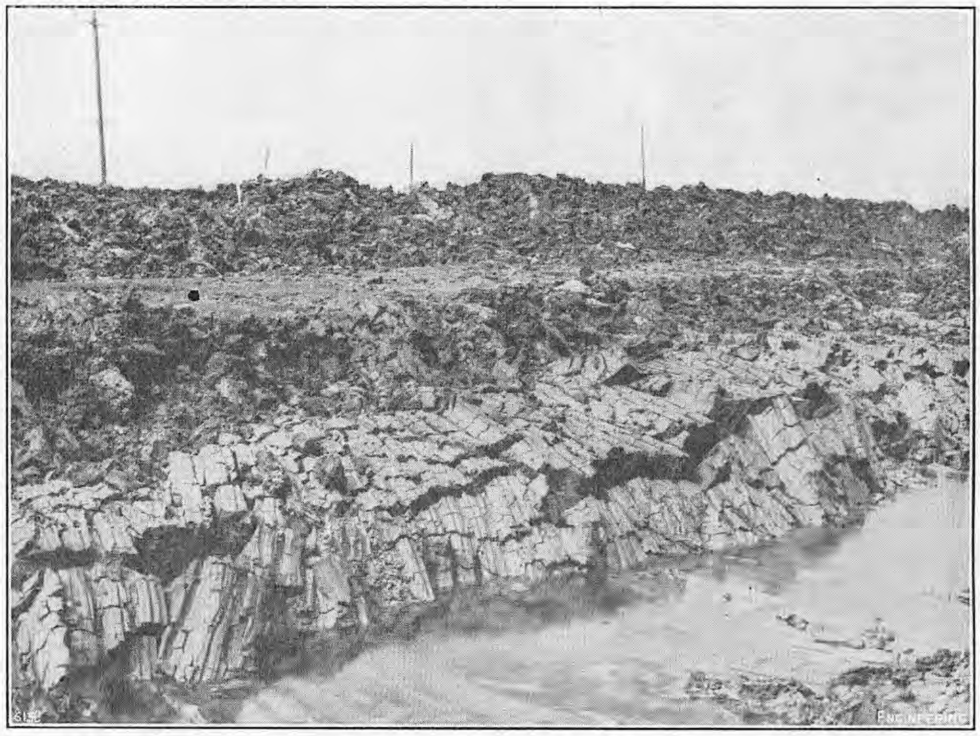


FIG. 5. EARTH SLIP IN BORROW PIT.

The reclaimed area consisted of inadequately drained marshes situated at the base of the hills on the west side of Southampton Water, between Fawley and Calshot. This area of 200 acres was originally about 6 ft. below high water, but was protected from tidal inundation by a small embankment. Since the reclamation was finished, about a quarter of the area has been sown with grass seed, and when it has completely drained and settled it will be suitable for agricultural purposes—probably for grazing in two years' time. To contain the dredged material, a new enclosure embankment, 10 ft. above the level of the marshes, as shown in Fig. 6, opposite, was constructed by dragline excavators. The new embankment was built on the landward face of the old embankment, an existing ditch being filled in at the same time, using material dragged from a borrow pit, as shown in Fig. 7. The borrow pit was kept as far away from the embankment as the booms of the excavators, sited on the landward side, would allow, to ensure the maximum possible stability. A jetty of steel bridge spans supported on timber piles, as shown in Fig. 4, herewith, was constructed to carry the pipeline a distance of about 800 yards from the reclamation dredger, which was permanently moored near the low-water line, to the reclamation area. The report of Soil Mechanics, Limited, is given in abridged form below. It was signed by Mr. I. K. Nixon, and by Dr. Hugh Q. Golder, by whose permission, and that of the contractors, we are enabled to make use of it.

The purpose of the investigation was to analyse the proposal to form a reclamation area on the marshes south of Ashlett. It is proposed to form an enclosure by raising the height of the existing sea-wall, which is an earth bank some 6 ft. high with brushwood protection on the seaward slope. In places this protection is badly in need of repair. The height of the existing bank is such that it is 1 ft. above the level of the highest water level recorded in Southampton Water. The dredged material, suspended in water, would be pumped into the area between the new bank and the rising ground behind the marshes. Three temporary culverts in the proposed bank would allow the water to escape after the dredged material had settled. The Dredging and Construction Company requested that an analysis be made in respect of the design of the new bank and the allowable depth of dredged material which might be placed in the area.

The marshes to be reclaimed stretch for some $1\frac{1}{2}$ miles on the west bank of Southampton Water, the width varying from 200 to 400 yards. On the east side the marshland is enclosed by the old sea-wall, beyond which are the "saltings." These saltings, two-thirds of a mile wide, are just below high-water level, and are composed of very soft clay covered by sedge grass. They contain numerous meandering creeks which drain off the water after each high tide (as Fig. 1 shows). On the west side the ground rises sharply. The marshes are very flat, and at a level of + 4 ft. N.D. (Newlyn Datum); this is 2 ft. below the level of the saltings.

The positions of the borings, shown in Fig. 3, on page 737, were determined by the Dredging and Construction Company. Three groups, each of two boreholes, were put down on the line of the existing sea-wall. Each borehole was close to the wall, one on the marsh and the other on the salting. One borehole in each group was carried down to the bottom of the soft clay and the other until the soil was seen to be similar to that in the first bore. This depth was generally 18 ft. Three other shallow boreholes were put down in the centre of the marsh, at approximately equal spacing. All the boreholes revealed similar ground, consisting of about 45 ft.

RECLAMATION OF MARSHES AT SOUTHAMPTON.

Fig. 6. DESIGN PROFILE OF BANK.

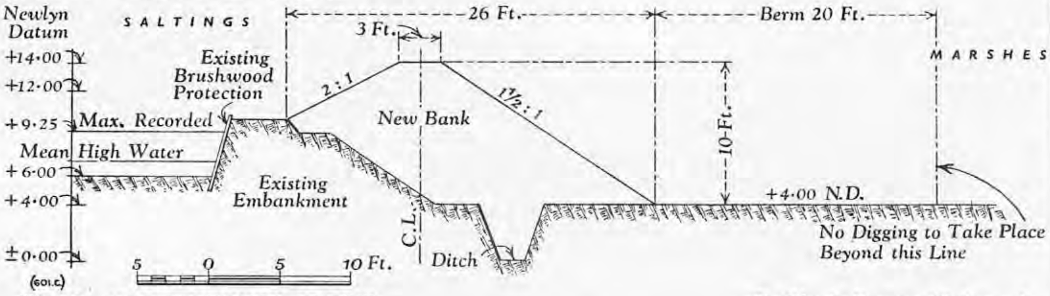


Fig. 7. STABILITY ANALYSIS OF BANK BUILT IN ONE OPERATION.

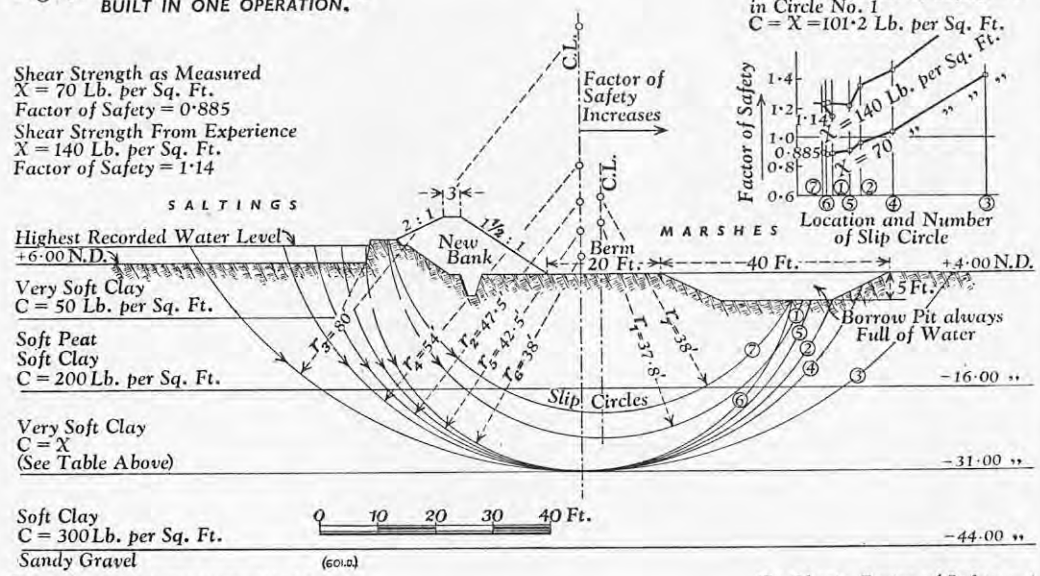
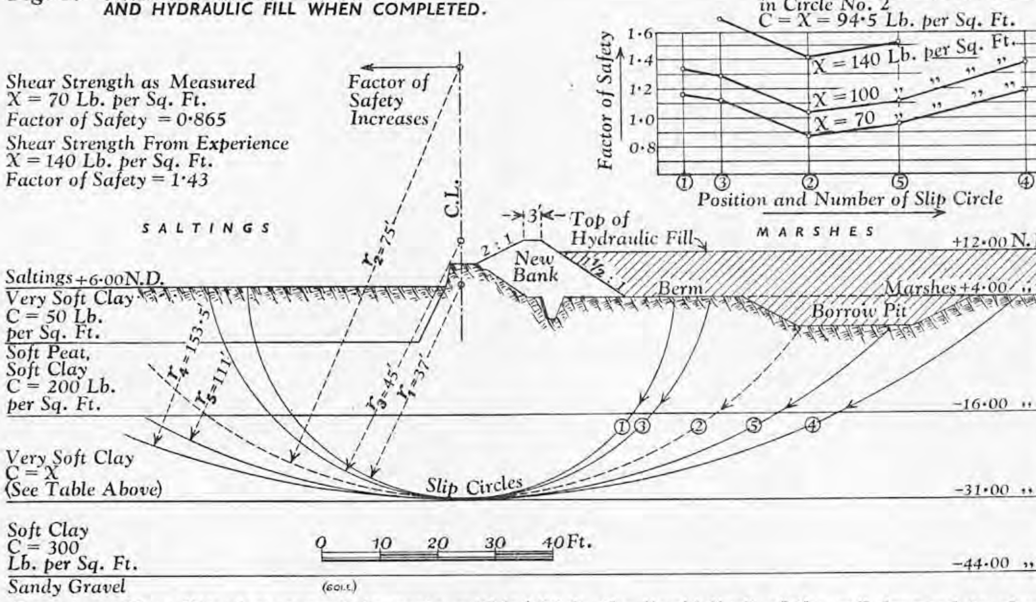


Fig. 8. STABILITY ANALYSIS OF BANK AND HYDRAULIC FILL WHEN COMPLETED.



of soft grey-blue silty clay, organic in parts, within which, at a depth of 12 ft., there was a stratum of peat about 4 ft. thick. Below the soft clay there was sandy gravel. The deep boreholes were terminated in this stratum. It would be reasonable to assume that this sandy gravel continues until the Barton clay is reached. It is of interest to note that in the centre of the site (borehole No. 3) the level of the sandy gravel was much higher than it was either to the south or to the north (boreholes Nos. 1 and 5). The boreholes on the marsh revealed a hard crust approximately 2 ft. thick. Ground-water level was 1 ft. below marsh level. Both disturbed and "undisturbed" samples of the soil were taken from the boreholes. The "undisturbed" samples were taken at approximately 5 ft. intervals in the deep boreholes.

The classification tests revealed that the soft clay above the peat stratum and immediately below it had a liquid limit of about 100 to 110 per cent. Visual examination of the soil showed that it was very organic, with occasional small peaty inclusions, which may have been the reason for the high value of the liquid limit. Below a depth of about 20 to 25 ft. the liquid limit of the soil dropped to about 80 per cent. The moisture content of the soil was always very high (except for the surface crust) and much closer to the liquid limit than the plastic limit. Although the results of the moisture content were rather erratic, it was possible to detect a small reduction with increasing depth, except for the peat samples. Certainly, there was no increase of moisture content with increasing depth.

All the "undisturbed" samples of soil were found to be purely cohesive and non-frictional for conditions of no change in moisture content. Three specimens of each sample were tested, and the shear strength was taken as one half of the mean compressive strength. Graphs were plotted showing the variation of the measured value of the shear strength with increasing depth. The shear strength of a thick stratum of a normally-consolidated clay soil generally increases with depth, according to the increase in the overburden pressure. In the case of a stratum deposited below water, the shear strength of the soil at or near the surface is almost zero, but, where the surface has become exposed to the atmosphere, surface hardening due to drying takes place, and this can extend to a depth of 15 to 20 ft. However, below this depth there should be a gradual increase in the shear strength with increasing depth, whatever the surface conditions. Quantitative examples of the value of this increase of shear strength with increasing overburden pressure have been published by Professor A. W. Skempton.* For a soil with a liquid limit of 80 per cent., it is tentatively suggested that the ratio of shear strength (c) to effective overburden pressure (p) $= 0 \cdot 3$. For higher values of the liquid limit the ratio increases.

The results of the shear-strength measurements for the majority of samples taken from below 20 to 25 ft. are not in accordance with the above remarks: the shear strength is very much lower than it is higher up, the ratio $\frac{c}{p}$ being $0 \cdot 14$ for boreholes No. 1 and 3 and $0 \cdot 09$ for borehole No. 5. This means that the shear strength as measured is just below half of what would be expected. The reason for this discrepancy may be due to disturbance when sampling, as the sampling of very soft clay is difficult. By carrying out vane tests on the site it should be possible to confirm this increase of the shear strength, as this form of testing is carried out on the soil *in situ*.

As a result of these various considerations and of the measurements made, the conditions shown in Table I have been assumed in the design of the bank and the thickness of dredged material. The similarity of the results for the various boreholes suggested that the conditions are similar along the whole of the bank.

TABLE I.—*Conditions Assumed in Design of Bank.*

Depth, Ft.	Shear Strength Below Saltings, Lb. per sq. ft.	Shear Strength Below Existing Bank and Marsh, Lb. per sq. ft.
0–10	50	200
10–25	200	200
25–40	70 (as measured) 140 (from experience)	70 (as measured) 140 (from experience)
40–50	300	300

As the soil excavated from the borrow pit is to be allowed to dry out, thereby increasing its strength, the profile of the new bank will depend upon the strength attained. The design shown in Fig. 6 has a top width of 3 ft., a seaward slope of 1 in 2, and a landward slope of 1 in 1½. It was recommended that attention be directed to grading the top and side slopes to prevent softening due to the action of rain and frost, and to maintenance of the existing sea-wall, it being assumed that this would completely protect the new bank from the effect of erosion by wave action. The height of the new bank is dependent upon the strength of the subsoil. Assuming that the design strengths given in Table I are applicable, the new bank might be built to a height of 10 ft. This would probably cause the peat stratum to consolidate, making it necessary to add to the bank from time to time. Nevertheless, by building the bank in stages, settlement due to overstressing would be reduced, as the interval of time between each construction stage would allow the soil to increase in strength.

The possibility had to be considered of a slip involving the bank and the borrow pit prior to filling the area, a form of failure which is more critical than a slip involving the bank and the saltings (where there are no creeks). As it is proposed to use a dragline to excavate the soil and place it on the line of the bank, practical considerations suggested a space of 20 ft. between the bank and the pit. If the bank is built in one operation, then the borrow pit must remain full of water and the shear strength of the soft clay below the peat would need to have a shear strength more than twice that measured in the laboratory. The stability analysis of the bank built in one operation is shown in Fig. 7, herewith. This might be possible but it cannot be relied upon. Therefore it would be necessary to build the bank in two or more stages. In this way, the disturbing forces promoting a slip are reduced and the factor of safety is consequently increased. The borrow

* "Vane Tests in the Alluvial Plain of the River Forth near Grangemouth," by A. W. Skempton. *Geotechnique*, vol. 1, No. 2 (1948).

pit must, of course, be refilled with dredged material prior to commencing a new pit for increasing the height of the bank. An analysis for the bank at one-half of its final height, with the borrow pit full of water, showed that the factor of safety against a slip occurring is 1·02. However, this is based on the measured values of the shear strength, and in view of the actual strength of the very soft clay being probably higher than that ascertained, the safety factor would be correspondingly higher. If the shear strength of this very soft clay is 140 lb. per square foot, the safety factor will be 1·34. It is recommended that, at all times, the berm is maintained at 20 ft. and that the depth of the borrow pit does not exceed 5 ft. at any stage.

The criterion determining the allowable thickness of dredged material which can be placed in the reclamation area is the possibility of a slip involving a settlement of the bank and the fill behind, and a corresponding heave in the area of the saltings. An analysis of this form of possible failure is given in Fig. 8, on page 739. The results show that, for 8 ft. of fill, the safety factor is 1 if the strength of the soil below the site is as measured, with the exception of the very soft clay below the peat; this must have a strength of 100 lb. per square foot. Although this is more than the measured strength for this soil, it is less than the strength that it possibly has, according to experience. Therefore, it was suggested that 8 ft. of fill might be placed over the area. It is of interest to note that, for a thickness of 7 ft., the factor of safety against sliding is 1·33, using the measured strengths, including those of the soft clay (70 lb. per square foot).

The addition of the dredged material over the site would probably cause settlements of the existing level of the marshland due to the consolidation of the peat, but this was thought to be of no consequence. The weight of the filling would increase the strength of the soil below, due to the settlement and consequent reduction in the moisture content. If the soft clay below the peat has, in fact, the strength as measured, the possibility of squeezing out must be investigated. The possibility of lateral flow was calculated by the formula (from an unpublished report to Soil Mechanics, Limited, by A. W. Skempton and A. W. Bishop):

$$q + \gamma D = c\left(2 + \frac{\pi}{2} + \frac{b}{2a}\right)$$

where

q = pressure due to dredged material.
γD = overburden pressure.
c = shear strength of the soft material.
$2a$ = thickness of soft layer.
b = half width of the reclamation area.

Assuming $2a$ = 15 ft., D = 20 ft., q = 900 lb. per square foot, and the factor of safety = 1·1, the required value of c would be 68 lb. per square foot for a value of b = 600 ft. The possibility of squeeze is greatest at the position of least width of the reclamation area. This corresponds to approximately 600 ft. According to the formula, it is seen that, for this width, with a safety factor of 1·1, the soft clay should have a strength of 68 lb. per square foot. This is equivalent to the measured value.

The allowable thickness having been determined according to the considerations described above, it was necessary to check that there would be no possibility of the bank sliding under the horizontal pressure of the fill. Table II, below, gives the conditions at two different depths.

TABLE II.—*Conditions Affecting Possibility of Bank Sliding.*

Position of Surface of Sliding.	Horizontal Pressure Due to Hydraulic Fill, Lb. per Ft. Run.	Resistance to Sliding, Lb. per Ft. Run.
At top of existing bank, 4 ft. below top of new bank	128	5,250
At base of bank at marsh level	2,048	9,450

NOTE.—The shear strength of the soil in the bank is assumed to be 300 lb. per square foot; it should be higher.

From the figures given in Table II, it is seen that, in both cases, the resistance is greater than the pressure due to the water in the fill.

To gain the maximum amount of increase in strength of the soil, the report concluded, the fill should be placed as slowly as possible. Therefore it would be advantageous to use all the reclamation areas at the same time rather than completely to fill each one separately. The rate of consolidation of the dredged material itself would be increased materially if it were possible to place initially over the reclamation area a layer of coarse material.

Though the report recommended building the bank in two stages, the contractors decided to build it in one. As a result, several slips occurred—as had been predicted—but they were rectified. The contractors were prepared for this, however; they considered that the inconvenience due to slips was more than offset by the ease of construction in one stage. Fig. 5 shows a slip in the borrow pit.

LITERATURE.

Stereoptics: an Introduction.

By LESLIE P. DUDLEY. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 15s. net.]

THOUGH the Victorian vogue of the stereoscope has waned, interest in stereoscopic pictures is now reviving as a result of important new developments that have taken place in recent years. As one of the chief contributors to progress in this field in this country, Mr. Dudley has felt the need of a convenient single word to cover all that pertains to the theory and practice of stereoscopy and the one proposed by him serves as the title to this book.

The appreciation of relief is a consequence of binocular vision, and the illusion of relief can be recaptured by viewing a pair of photographs representing left and right eye views of the same scene under conditions which promote binocular fusion of the respective images. Methods of producing simple stereograms and the classical methods of viewing them devised by Wheatstone, Brewster and others are described in the opening chapter, wherein attention is also directed to the reversal of the relief that ensues when the two components of a stereogram are transposed; which is known as "pseudoscopy." Chapter II is devoted to the use of polarised light to enable pictures to be viewed in stereoscopic relief. Though orginally suggested as far back as 1890, this did not become really practicable until the invention of "Polaroid" in 1934. Mention might have been made of the means adopted to orientate the microscopic doubly-refracting crystals which is the essential feature of the Land process. Alternative methods of arranging the stereoscopic image pairs on standard and sub-standard film and for projecting them are described, including a system, due to the author, which notably improves screen illumination. Reasons are given for preferring methods based on the split field rather than the alternate frame principle. The following chapter deals with anaglyphic processes in which the two component views are superimposed and seen three-dimensionally when examined through a pair of complementary colour filters inserted in a spectacle frame. In the system developed by the author, ordinary colour stock film is used to produce anaglyphs directly in natural colour.

Part II is concerned with auto-stereoscopic photography, whereby the impression of solidity is obtained without the necessity of using any individual viewing device. The first successful system—due to Ives (1902)—produced what he termed "parallax stereograms," consisting, in effect, of contiguous narrow strips equivalent to corresponding alternate elements of the picture pair in an ordinary stereogram. Methods of taking and viewing still and cinematograph pictures based on this principle are described, together with modifications designed to overcome its main disadvantage, namely, the presentation of an equal number of orthoscopic and pseudoscopic viewing positions. One drawback to stereograms taken with a stationary camera is the distortion that results unless they are viewed from substantially the same standpoint as that occupied by the camera. How this can be overcome by traversing the camera over an arc of a circle centred on the centre of interest of the scene is explained in Chapter V. A further advantage of these "parallax panoramagrams," as they are called, is that pseudoscopic viewing zones can be rendered much less obtrusive. Details are also given of the very remarkable technique of integral photography, proposed by Lippmann in 1908, which, since the introduction of lenticular film, is now being developed, notably by Zafiropulo and Saint Genies.

Methods for locating foreign bodies or flaws are vital in medical and industrial radiography, and recent improvements in stereoscopic technique proposed by the author, using direct or indirect methods and moving either the source or the subject, are outlined in the concluding chapter, together with another promising innovation—the stereoscopic graticule.

This stimulating little book breaks new ground and opens up fresh possibilities which visitors to the Festival cinema, and others, will appreciate. Those desiring a fuller discussion of the problems of stereoptics will be interested to note that Mr. Dudley intends to follow this excellent introduction with a treatise on this fascinating subject, in which space will doubtless be found for topics not dealt with in the present book, such, for example, as stereoscopic range finders.

The Hardness of Metals.

By D. TABOR. Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 15s. net.]

THE quality of hardness is at once one of the easiest attributes to appreciate and one of the most difficult to define precisely. Recognition of the quality of hardness is widespread, but the best that most people, on the spur of the moment, could provide as a definition of "hard" would be "not soft"; which is a description, perhaps, but scarcely a definition. Even Dr. Tabor, in this excellent review of the subject that he has contributed to the Oxford University Press series of "Monographs on the Physics and Chemistry of Materials," rather begs this particular question; "in general," he says, "hardness implies the resistance to deformation," but he proceeds at once to point out the difficulty that if, by "deformation," is meant "permanent deformation," then "a substance such as rubber would appear to be harder than most metals." Since, however, the book is concerned only with the hardness of metals, he has sufficient justification for dropping the awkward example of rubber and turning to the methods of making hardness measurements.

Thenceforward, the book becomes scientifically factual as, in successive chapters, the author discusses, with admirable clarity and a notable economy of words, hardness measurements by spherical indenters, the deformation and indentation of ideal plastic metals and of metals which work-harden, the practical considerations of "shallowing" and elastic recovery, the use of conical and pyramidal indenters, dynamic or rebound hardness, and the area of contact between solids. There are no fewer than six appendices, dealing with Brinell, Meyer and Vickers hardness measurements and the conversion factors which relate one to another, the connection between hardness and ultimate tensile strength, and a selection of typical hardness values. Within the field that the author has set out to cover, the treatment is thorough; and the other works cited, if systematically studied, make it as exhaustive as most engineers and a large proportion of physicists are likely to require. It should be noted, however, that there is no more than an introductory reference to the subject of scratch hardness (a method of testing which "does not easily lend itself to a theoretical analysis") or to that ingenious device, the Herbert pendulum hardness-tester, which is similarly dismissed because "it does not lend itself readily to theoretical treatment." As Dr. Tabor admits that "this method is of considerable interest," some readers may regret that more space has not been devoted to it; more especially to its action on work-hardening metals, and to the parallelism between the pendulum readings and the Brinell numbers for the same materials, which E. G. Herbert himself could only explain as a remarkable coincidence. The methods most commonly used are well covered, however, and the book should prove of value to those desiring a sound basic knowledge of the subject and of interest to many more.

THE IRON AND STEEL INSTITUTE.

(*Continued from page* 710.)

Continuing our report of the recent London autumn general meeting of the Iron and Steel Institute, we deal now with the "Symposium on Stresses in Ingot Moulds," held on the afternoon of Wednesday, November 21. In our last issue, we gave abstracts of the first two papers of the symposium and we deal now with the remaining three and with the two further papers submitted for discussion with the symposium. The first of these papers, by Dr. R. T. Fowler and Mr. J. Stringer, dealt with ingot-heat conservation, and the second, by Mr. A. Jackson, was on the subject of 10-ton ingot moulds.

Stresses in Ingot Moulds.

The third paper in the symposium dealt with the "Growth Characteristics of Some Cast Irons Used for Ingot Moulds," and was by Mr. W. C. Heselwood and Mr. F. B. Pickering, of the United Steel Companies, Limited. The authors stated that the growth of 16 irons used for the manufacture of ingot moulds had been examined at temperatures up to 850 deg. C. A detailed preliminary examination of five of the irons indicated that, in 5 hours, maximum growth took place at about 700 deg. C. Little growth occurred below 600 deg. C., and there was no growth above the Ac_1 temperature. It had been found, however, that heating to temperatures above that of Ac_1 could greatly affect the amount of growth which took place at lower temperatures. The measurement of the growth occurring in 5 hours at 700 deg. C. under conditions of limited access of air (to minimise scaling), had been finally adopted as an arbitrary test for growth. Good agreement was found between laboratory growth tests and the growth resulting from the works-annealing of certain ingot moulds. Within the range of analysis studied, it was found that the growth under the conditions of the adopted test could be estimated with fair accuracy from the relation :—

$$\text{Growth, per cent.} = 0{\cdot}32 - 0{\cdot}21\ \text{Mn} + 0{\cdot}13\ \text{Si} - 0{\cdot}73\ \text{P}.$$

The title of the fourth paper was "Note on Relaxation Tests on Cast Iron" and its author was Mr. J. Woolman, who stated that, in view of the possible effect that growth might have on the stresses, induced in cast-iron moulds during use, some relaxation tests had been carried out to determine the rate of relaxation of stress under constant deformation. The first test was carried out at 450 deg. C. on an iron sample initially loaded at 4 tons per square inch, and the load was then reduced manually by sliding the jockey weight of the testing machine along the beam by a handwheel; the beam thus remained horizontal and the test piece was maintained at constant length. The results showed that, at 450 deg. C., the stress relaxed quickly at first but did not reach constant values even after 19 hours. In a second test on a sample of the same iron at 700 deg. C., the specimen immediately broke on reaching a load of 4 tons per square inch. A repeat test was carried out with an initial stress of 2 tons per square inch, at 700 deg. C., but the stress fell so rapidly that it could not be followed, and, before a reading could be taken the specimen broke. The indications, however, were that the rate of relaxation was extremely rapid, so that it was unlikely that high stresses could build up at temperatures when growth of iron occurred. Thus it was improbable that growth could have any influence on the stresses induced in an ingot mould during use.

The fifth and last paper was entitled "Determination of Surface Stresses in Ingot Moulds" and was by Mr. M. W. Buttler and Mr. W. H. Glaisher. It described work carried out in the Steelmaking Division of the British Iron and Steel Research Association. The authors stated that when a cast-iron ingot mould was filled with molten steel, stresses were produced in the walls owing to the steep temperature gradients set up. By measuring the consequent strains, it was possible to evaluate these stresses, if certain properties of the mould iron were known. A temperature survey of a mould during use showed that certain parts of the mould did not attain the minimum temperature for rapid growth (650 deg. C.), while other parts remained in the temperature range for most rapid growth for a considerable period. The effect of this growth on the cracking of moulds was probably small, since it occurred at temperatures above 650 deg. C., when the mould iron was in a plastic condition. It might, however, be a contributory factor to "crazing" of the inner surface of moulds.

The paper on "Ingot Heat Conservation: Ingot-Mould Temperature Measurements," by Dr. R. T. Fowler and Mr. J. Stringer, gave an account of work conducted in the Plant Engineering Division of the British Iron and Steel Research Association. It was presented by Dr. Fowler. The authors stated that measurements of the surface temperatures of an ingot had been made, and the technique of temperature measurement by fixed thermocouples had been extended to include temperatures within the walls. Two trials had been made with the mould initially at a temperature of 30 deg. C., and one trial with the mould at 125 deg. C., the latter being representative of normal practice. Temperature gradients and isotherms had been plotted to give a picture of the overall temperature distribution throughout the mould at various times from teeming. From the results obtained, the heat content of the mould had been calculated and the amount of heat removed from the steel during solidification estimated. In presenting the paper, Dr. Fowler added that, since it had been published, weights and measurements of test ingots of killed and rimming steel had shown that the assumed density of 7·856 grammes per cubic centimetre used in calculating the heat content in calories per gramme was too high and that figures of 7·3 and 6·67 grammes per cubic centimetre, respectively, were more appropriate. Consequently, some of the data given towards the end of the paper needed correction.

In his paper entitled "Ten-Ton Ingot Moulds: A Comparison of Design and Conditions of Use," Mr. A. Jackson, of the Appleby-Frodingham Steel Company, Scunthorpe, described an investigation carried out for the Steelmaking Division of the British Iron and Steel Research Association. He stated that the introduction of the taper-top mould, designed to overcome certain types of failure in the open-top mould, had resulted in a decrease in mould consumption from 17·5 lb. to 14·6 lb. per ton. Similarly, a new and heavier design of bottom plate had produced a rather striking fall in bottom-plate consumption from 15·1 lb. to 4 lb. per ton. Using taper-top moulds at a temperature of about 50 deg. C., and with other conditions as uniform as practicable, decreasing tap-to-strip time from 127 to 44 minutes reduced the mould consumption, with the usual method of failure, from 18·2 lb. to 9·6 lb. per ton. If the moulds were allowed to cool for at least 36 hours between heats, being used each time at atmospheric temperature, their life was reduced by about 10 per cent. with both long and short tap-to-strip times. Basically, in all tests, failure was normally caused by a horizontal crack in the broad side of the mould, frequently accompanied by a vertical crack growing downwards from the centre. There was, however, a fundamental difference in the type of crazing that developed. With the long tap-to-strip times, the crazy pattern was of small mesh and the markings were depressions. Rapid stripping produced a very coarse mesh of projections, each subdivided by a fine crack. From some part of this pattern major failure commenced. A few moulds failed prematurely owing to vertical cracks on the narrow side and it was tentatively suggested that this type of failure had its origin outside the sphere of the user. Neither order of teeming nor chemical analysis, within the limits studied, appeared to have any important effect on mould life.

Mr. N. H. Bacon, in opening the discussion on the five papers in the symposium and the two papers presented subsequently, said that the paper by Dr. Fowler and Mr. Stringer was of great interest from the viewpoint of the heat absorbed by the mould, and it showed how strongly the heating of the mould was affected by the surroundings—by the pit walls, by full or empty moulds and by slag pots. It was surprising that moulds should still be treated in such barbarous fashion. Some means of cooling, for example, by the agency of fans, might pay good dividends in improved mould life. Further, the irregular heating of the mould was one of the most important factors in reducing their service usefulness. Mr. Jackson had largely reduced this difficulty by designing the bottom plates in such a manner that the moulds were regularly spaced.

Mr. Jackson had achieved what must be a world's record for long mould life, combined with low mould consumption. He had obtained a life of about 200 casts for a 10-ton slab mould, with a mould consumption of 11 lb. per ton of steel; which was a remarkable achievement. This work, in addition to demonstrating the importance of removing the mould from the ingot at the earliest possible time, compatible with good steelmaking practice, had proved that moulds having an initial temperature of about 50 deg. C. suffered less damage during service than moulds which had cooled to room temperature. That was important, because at one time it was thought that the cooler the mould the better it would be. A temperature of 50 to 70 deg. C. was probably the optimum, and if it were allowed to go above that, reduced mould life would result. The use of moulds neither too warm nor too cold was, of course, difficult to ensure, but those melting shops which took steps, by careful control, to try to ensure it found that, in the long run, it paid handsomely in reduced mould consumption.

The paper by Mr. Heselwood and Mr. Pickering was of particular interest because it gave some indication that irons having the higher growth rates resulted in moulds giving shorter lives. This research had really originated following some work by Mr. S. W. Palmer, of the British Cast Iron Research Association, who in his Report No. 195, "Thermal Expansion of Cast Iron," had shown that the growth characteristics of iron depended chiefly on the silicon, manganese and phosphorus contents, and that higher silicon induced greater growth and higher manganese and phosphorus reduced the rate of growth. Since a number of companies had also found that mould life varied with variations of these three elements, it appeared that growth and life were correlated in some fashion and bore some relationship. The irons dealt with by Mr. Palmer, however, were not of the type used for making ingot moulds; they were higher in phosphorus and silicon. The work done by Mr. Heselwood and Mr. Pickering had been carried out on iron samples cast alongside the ingot moulds, and was therefore of special value in connection with the study of mould performance. It seemed that the growth characteristic was important and merited further study. What now required to be done was to find some means of making growth tests rapidly in the foundry. He had seen a most interesting paper by two French friends, Messrs. Rocquet and Olette, which apparently did give a practical method of conducting growth tests on a works basis with sufficient accuracy.

Mr. M. Olette, on being called upon by the President, said that in a recently published report* on a study carried out in France at the Institut de Recherches de la Sidérurgie, Mr. Rocquet and he had tried to define the part played by the different factors affecting cast-iron growth within the range of temperature usually found in ingot moulds. For this purpose, a series of cast-iron bars, taken from one melt, had been subjected to a number of cycles of heating up to a selected temperature and cooling down to 400 deg. C., first *in vacuo* and then in an oxidising atmosphere. The cast iron used had the following percentage composition, with slight changes from one test-piece to another: total carbon 3·24, graphite 2·70, combined carbon, 0·54, silicon 1·62, manganese 0·58, phosphorus 0·12, sulphur 0·08. The measurements of linear growth were made between two marks milled on the bars, before and after the treatment. The test-piece was put in a transparent silica tube externally heated by a Nichrome-wound furnace. The tests *in vacuo* showed that below the transformation point Ac_1

* Rocquet and Olette, "Gonflement des Fontes," *Fonderie*, July 1951.

(about 775 deg. C. for the cast iron studied), and after about 20 alternate heating and cooling cycles, the linear growth was small and approached a limiting value of about 0·5 per cent. A micrographic examination of the bars, before and after treatment, showed that pearlite and cementite were completely transformed into ferrite and graphite. These findings were in good agreement with Messrs. Heselwood and Pickering's results obtained after a five-hour isothermal treatment at 700 deg. C. On the other hand, temperature cycles up to 850 deg. C., namely, above the transformation point, gave greater growth, but, whereas in the previous test the percentage growth was nearly constant after the first 20 cycles, in this test the growth increased slightly but steadily even after 60 cycles.

Tests in an oxidising atmosphere at 700 deg. C. gave growth values smaller than those found at 740 deg. C. *in vacuo*. At this stage, graphitisation was probably not complete and the influence of oxidation was negligible. At 750 deg. C., the growth was higher than at 740 deg. C. *in vacuo*: here, oxidation began to have an influence. Above the transformation points, at 800 deg. C. and 850 deg. C., the growths were also very much greater than at 850 deg. C. *in vacuo*. This apparently showed the large influence of oxidation phenomena on cast-iron growth. Some determinations of the silica content in bars subjected to temperature cycles in oxidising atmospheres indicated the existence of a relation between the percentage growth and the percentage of the total silicon oxidised. Determinations of the silica content in ingot moulds after use had shown that an important part of the silicon was oxidised near the inner wall. The application of the results obtained with the bars showed that a 20 per cent. volume growth should take place on the inner surface of the ingot mould in a cast-iron layer 10 to 15 mm. thick in the middle of the faces. In the corners, where the temperatures reached were lower, this layer was thinner after such a growth.

Mr. F. A. Gray, speaking on the paper by Dr. Fowler and Mr. Stringer, said that at present the minimum time allowed between tapping and stripping was largely arbitrary, and there was little doubt that there was a considerable variation in the stripping times between various works using the same types of ingot. There was a point at which the heat content of the cooling ingot was identical with that required for rolling, and the object, therefore, was to attain this ideal as nearly as possible. One method was to determine the heat flow from ingot to mould, and, from this, to deduce the temperature and heat conditions in the ingot itself, and this line of attack had been followed in the paper.

The assessment of the conditions within an ingot merely by temperature measurements, while giving valuable information, was an indirect method, and the ideal would be to measure the temperature in the ingot itself. This, however, involved considerable practical difficulties, and also needed a benevolent works manager who was prepared to scrap a few ingots for the advancement of knowledge. Interest in this problem was by no means confined to the heat economist; it was obviously equally important to the metallurgist and steelmaker. Mr. Jackson's paper showed how reduced stripping times had most strikingly increased mould lives. It would be interesting to hear from Mr. Jackson what effect these reduced stripping times, and therefore higher-temperature ingots, had on the output and fuel consumption of the soaking pits. One piece of information of particular interest was the statement that radiation and convection loss was only 10 per cent. of the heat gained by the mould; in other words, the mould took up 90 per cent. of the heat flowing from the ingot. If this were true, would not ingot cooling be accelerated by using thicker moulds? It had been seen from Mr. Jackson's paper that the new designs of moulds and bottom plates, which gave considerably increased lives, both had thicker walls.

Mr. H. Brooke Freeman stated that, while his colleagues viewed the paper by Dr. Fowler and Mr. Stringer as a contribution to the problem of ingot-heat conservation, he was interested primarily from the metallurgical aspect. He wanted to know the rate of heat extraction from the ingot in the first few seconds following teeming; during this time the skin of the ingot was formed, and the quality of that skin would be reflected in the surface condition of the finished product. He was concerned particularly with low-carbon ingots of $6\frac{1}{2}$ to $8\frac{1}{2}$ tons, cast in slab moulds, namely, rimming steel of about 0·07 per cent. carbon. The rim of a rimming steel ingot was composed of five layers. The first consisted of spattered nodules ejected by the steel as it was rising in the ingot. Immediately on top of this first layer came the second layer, quenched on to the first layer by the drastic cooling effect of the mould. The third layer was formed under the reaction of $FeO + C$, giving $CO + Fe$, yielding a very dense and solid skin. The fourth layer was that usually indicated by the "rim holes," and the fifth that indicated by "rim channels." In making fully-finished motor-car body sheets, and indeed in almost any product, the skin formation was important, because these layers determined the quality of the surface of the sheet. In the production of fully-finished sheets for motor-car body work the prime requisite was an ingot having a good skin. It was well known, in making low-carbon rimming steel, that extremes of mould temperature showed marked differences in the behaviour of the metal in the moulds. If rimming steel were teemed into a hot mould there was a very big difference in the surface condition of the ingot compared with that which was obtained when teemed into a cold mould. The method reported in the paper would appear to be capable of extension to provide the required information, namely, the temperature of the inner face of the mould.

Mr. J. W. Grant said that following the work done by Mr. Heselwood and Mr. Pickering, the British Cast Iron Research Association had in hand some experiments very similar to those concerning which Mr. Olette had spoken. These were conducted in a vacuum having a pressure of 10^{-3} mm. of mercury, which was the same as the pressure Mr. Olette had employed. The growths which they had obtained in certain conditions with a vacuum of that kind, however, had been as much as 30 per cent. These were on ingot-mould irons. It was of interest to mention that, in some cases, they had annealed the sample beforehand in air, and when that sample had then been subjected to the same cyclic treatment, namely, 100 cycles between 600 deg. and 900 deg. C., the growth was only 2 per cent. This was evidently due to oxygen penetrating into the metal and, at least temporarily, preventing the growth which occurred with the as-cast material.

Mr. M. J. Durand stated that the desirability of knowing the temperature of the inner wall of the ingot mould had been referred to. A method of estimating this had been tried at the Compagnie des Forges et Aciéries de la Marine et d'Homécourt. It involved inserting a piece of annealed steel through the wall of the mould and considering micrographically the change in the structure of the annealed metal. By this means they had found that the temperature was about 1,200 deg. C.

Mr. J. Woolman, replying to the discussion on behalf of the authors of the papers in the symposium, said that he had been particularly interested in Mr. Bacon's remarks. It was very unfortunate, of course, that insufficient progress had been made, to date, to apply any results obtained to ingot-mould design. The work was of a long-term order and could not be done quickly, but it had been shown that surface stresses could be determined, and a tool was thereby provided which would make it possible to determine the various factors of mould design. Turning for a moment to the correlation of life of moulds with calculated growth, one would expect to find a good relation between the life of moulds which failed by crazing and the growth characteristics as determined by Mr. Heselwood and Mr. Pickering or by Mr. Olette, but could not expect any relation between growth characteristics and life of moulds in the case of failure by major cracking, and especially those which failed early by major cracking. Those which failed late by major cracking might show a certain amount of correlation owing to the deterioration of the iron which occurred on repeated reheating.

Dr. R. T. Fowler, replying to the discussion on the paper of which he was joint author with Mr. Stringer, said that in B.I.S.R.A. they were attempting to use surface pyrometers more and more. In spite of the advantages of this thermocouple technique it was a clumsy method, and could not be used on more than one mould at a time unless, say, 10 calorimeters could be tolerated in the casting pit, which was verging on the preposterous. Their intention was, therefore, to use this test mould and move it about in the pit into various positions and measure the heat lost from the ingot at various times from teeming to stripping. If it were found that there was a satisfactory correlation between the surface temperature rise on the outside of the mould and the heat lost from the steel, the next stage would be to use only one thermocouple, placed at a convenient spot on the mould surface, and employ that as a reference point. The next step would be to dispense with the surface thermocouple and go on to a contact pyrometer, so that, visualised as routine work, a man would place the surface pyrometer on a selected point on the mould surface, measure the temperature rise, and then, by referring back to certain graphs, would be able to estimate the heat loss from the ingot, and, knowing the heat loss from the ingot, could then estimate how much heat had to be put back into it in order to bring it up to rolling temperature. That was the objective which B.I.S.R.A. wished to attain.

Their paper, he admitted, was a little out of date, inasmuch as in the past year they had done a great number of runs using this test mould and had obtained some very interesting information. They had gone right through the mould wall to within $\frac{9}{64}$ in. of the inner face and had carried out a complete series of runs. They had found that the temperature went up rapidly to about 700 deg. C. in 10 minutes, but after 100 minutes it levelled out at about 850-900 deg. C. on the inner face.

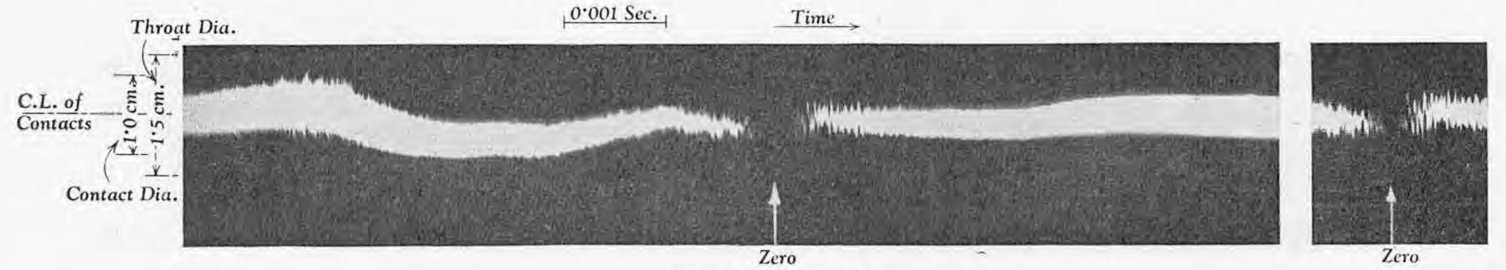
Mr. A. Jackson, who also replied, said that, in his works, they brought their ingots from the melting shop and dumped them into Gjers pits, which were rectangular covered holes lined with firebrick. A calculation enabled them to estimate when the ingots were ready for rolling, and this indicated that the heat loss in the Gjers pits was just half the heat loss outside. An ingot which was stripped in 40 minutes and put straight into the soaking pit could not be rolled for six hours, because it was not set; but if it were left standing exposed to the atmosphere on its car for $2\frac{1}{2}$ to 3 hours it could then be put into the soaking pit for an hour and thus would be ready for rolling much more quickly.

At this stage in the proceedings, the President of the Institute, Mr. Richard Mather, adjourned the meeting until 10 a.m. on the following day, Thursday, November 22.

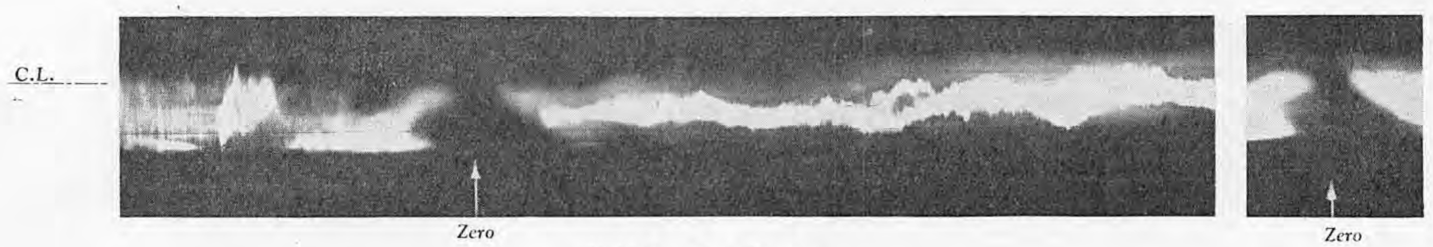
(To be continued.)

THE LATE MR. W. H. H. POWELL.—It is with regret that we record the death of Mr. William Howard Hinton Powell, chairman of the Vacuum Brake Co., and a former director of the Westinghouse Brake and Signal Co., Ltd., 82, York Way, Kings Cross, London, N.1. Mr. Powell, who died on November 13 at the age of 77, had been connected with the railway-signalling industry for over 60 years, 50 years of which were in the service of the Westinghouse Co. and its predecessors. After serving for ten years on the Taff Vale Railway, he joined McKenzie and Holland, Ltd., in 1900, first in the capacity of resident representative for Wales and Ireland, and later for northern England, Scotland and Ireland. In 1916, he was appointed London manager, but within a year was made works manager of the firm's establishment at Worcester. In 1919, he took over the works management of Saxby and Farmer, Ltd., at Chippenham, and prepared for the transfer there of the Worcester Works. This having been successfully completed, he came to London in 1922 as general business manager, later becoming general manager; and in 1935, was elected a director. Mr. Powell resigned his general managership in 1942, but remained on the board until 1950. Meanwhile, in 1936, he had been elected to the board of the Vacuum Brake Co., Ltd., and was made chairman in 1944. He was also chairman of the W. R. Sykes Interlocking Signal Co. and of Rockweld, Ltd., and a director of the Consolidated Signal Co. and the Railway Signal Co. Mr. Powell was elected an associate member of the Institution of Mechanical Engineers in 1906 and became a member in 1910. He had been a member of the Institution of Railway Signal Engineers since its incorporation in 1912.

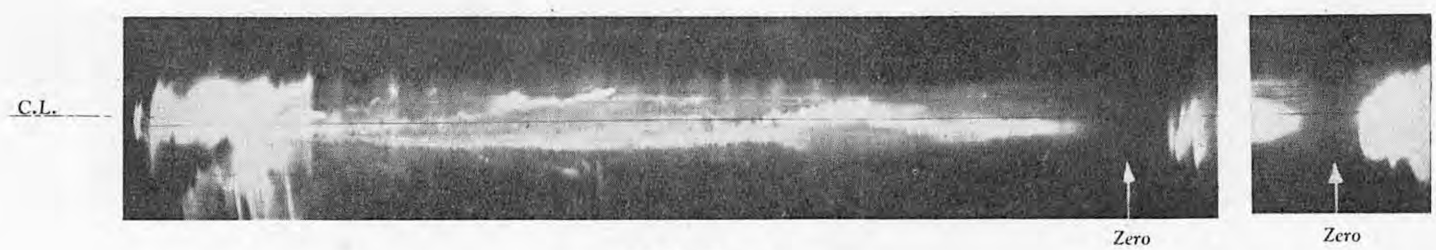
ARC FORM AND MOVEMENT IN AIR-BLAST CIRCUIT-BREAKER.



(a) 25 LB. PER SQ. IN.



(b) 10 LB. PER SQ. IN.



(c) NO BLAST.

FIG. 11. ARC MOVEMENT AT DIFFERENT GAS PRESSURES.

ARC FORM AND MOVEMENT IN AN EXPERIMENTAL AXIAL AIR-BLAST CIRCUIT-BREAKER.*

By F. O. MASON, B.Sc. (Eng.), A.M.I.E.E.

(*Concluded from page* 713.)

FIGS. 11 (*a*), (*b*) and (*c*), obtained in a similar manner to those in Fig. 10, on page 712, *ante*, were all taken 1 mm. above the throat, but at 25 lb., 10 lb. and 0 lb. per square inch reservoir gauge pressures, respectively. From these and Fig. 10 (*a*) it will be seen that, between 10 lb. and 25 lb. per square inch gauge, the arc changes from a more or less diffused form to the more distinct and filamentary form, particularly pronounced around the current-zero position. Records taken at pressures between these two values show that the filamentary form appears approximately at the time when the pressure is raised to a level sufficient to obtain the velocity of sound in the throat, i.e., roughly 15 lb. per square inch gauge in the arcing chamber. In Figs. 11 (*a*) and (*b*) it will be noticed that the arc column seems to be split, and formed with "streamers" running in parallel over various lengths of the photographs. It is difficult to interpret this effect, but it is most probably caused by streams of copper vapour or gas at varying degrees of ionisation and temperature. The evidence at present available, however, is not sufficient to make this point certain; indeed, in the diffused type of record the term "arc column" would be difficult to define. Figs. 11 (*c*) and 10 (*b*) show the first half-cycle of an arc, where it will be noticed that at the beginning the light emitted is much stronger than at following current-zero periods. This effect is characteristic of the beginning of arcing and is due to the blowing of the fine fuse wire which initiates the arc and appears to continue until the copper vapour from the fuse is dispersed by the air blast.

Observations in a Vertical Plane.—Figs. 12 (*a*), (*b*) and (*c*), page 744, are reproduced from photographs made with the camera raised, so that the slit aperture was parallel with and focused on the axis of the top and bottom electrodes in the manner previously described. These records were taken primarily with the object of determining whether the arc was moving in different directions at the same time for different positions along its length or whether it was moving in one direction as a whole at a given time. It should be noted that in Fig. 12 time is going from right to left. As in the case with the slit horizontal, the photographs have been reproduced to give the best overall picture so that the relative light intensities at different positions along the arc gap and during the arcing time can best be compared. Here again the small pictures to the right are of the current-zero period suitably reproduced. The records illustrated in Fig. 12 were made at different reservoir gauge pressures, and, as would be expected from the previous records, that made at a pressure of 10 lb. per square inch is diffused and indeterminate, whereas at the higher pressures the arc takes the more concentrated form already described.

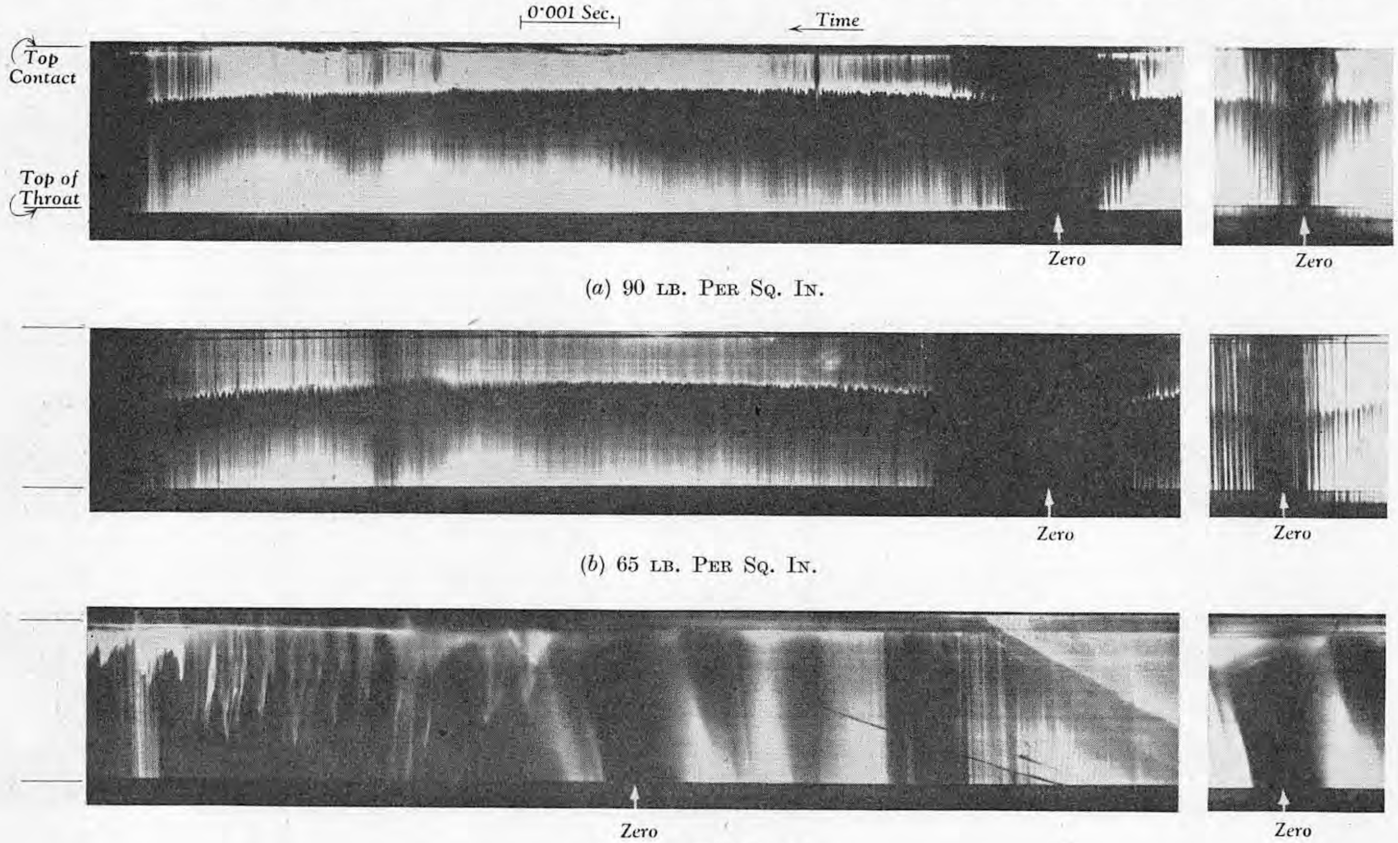
Fig. 12 (*c*) has been reproduced with the current zero in the middle of the record to show more clearly the difference between two consecutive half cycles, which is sometimes apparent at the lower pressures. This may be due to residual effects of arcing at these lower pressures influencing the following half cycle, a polarity effect, or merely because the blast is not always sufficient to maintain the arc more or less centrally and thus moving the position of the arc relative to the vertical centre line of the slit. From Figs. 12 (*a*) and (*b*)—at the higher pressures—it will be seen, by virtue of the alternating light and dark vertical bands, that the arc over the length photographed is moving generally into and out of the field of vision through the slit as a whole, except perhaps in the region just before current zero where the broken vertical white lines indicate that the arc is taking a more or less zig-zag form about its axis. In Fig. 12 (*a*) the restriking pulse, referred to previously, can be seen in the centre of the "dark" current-zero position and indicates, since it is not a continuous line, that the discharge is not entirely vertical. It is not surprising, in view of the narrowness of the camera slit, that the restriking pulse was rarely observed in photographs taken with the slit vertical.

One of the interesting features of Fig. 12 (*c*), made at 10 lb. per square inch, is the one or two dark lines running generally diagonally across the record towards the right-hand end. These are not blemishes, but are probably due to solid particles, most probably copper, moving along the arc gap in the line of the slit. The diagonal demarcations showing a general change of light intensity also noticeable would seem to indicate the movement of gas or vapour pockets along the arc gap and, since time is going from right to left, movement is upwards in the direction of the blast. If the long black diagonal line is caused by the movement of a solid particle, then it is moving with an approximately linear vertical velocity of 400 cm. per second. Incidentally, by deliberately introducing suitable particles into the gas stream, it may be possible in this way to measure gas velocities during arcing.

Another interesting feature of the records obtained at the higher pressures is—for want of a better term—the "serrated curtain" effect which is apparent throughout most of the half cycle. The varying light intensities in the vertical direction are largely due to the differing gas pressure zones and gradients, characteristic of gas flow through a nozzle at velocities above that of sound. These can be identified in the photograph, reproduced in Fig. 13, page 744, taken with a pinhole camera exposed through an appropriate neutral-density filter to the whole arcing space above the throat for the full arcing period (four half-cycles of current in this case). In general, the greater light intensity zones are at higher gas pressures than those of less intensity. Evidently, the height of the base of the zone of light at about 12 to 15 mm. above the throat varies rapidly throughout the half-cycle, giving the "serrated" effect shown in Figs. 12 (*a*) and (*b*) and the "striated" effect at the ends of the record, shown in Fig. 10 (*b*), taken with the camera slit horizontal at about the same level. It will be noted that the base of the cone of light varies in mean height throughout the half-cycle, becoming lower as the current approaches zero, and following the mean gas pressure in the throat. This explains why the "striated" effects in Fig. 10 (*b*) appear

* Based on Report G/XT 131 of the British Electrical and Allied Industries Research Association.

ARC FORM AND MOVEMENT IN AIR-BLAST CIRCUIT-BREAKER.



(a) 90 lb. Per Sq. In.

(b) 65 lb. Per Sq. In.

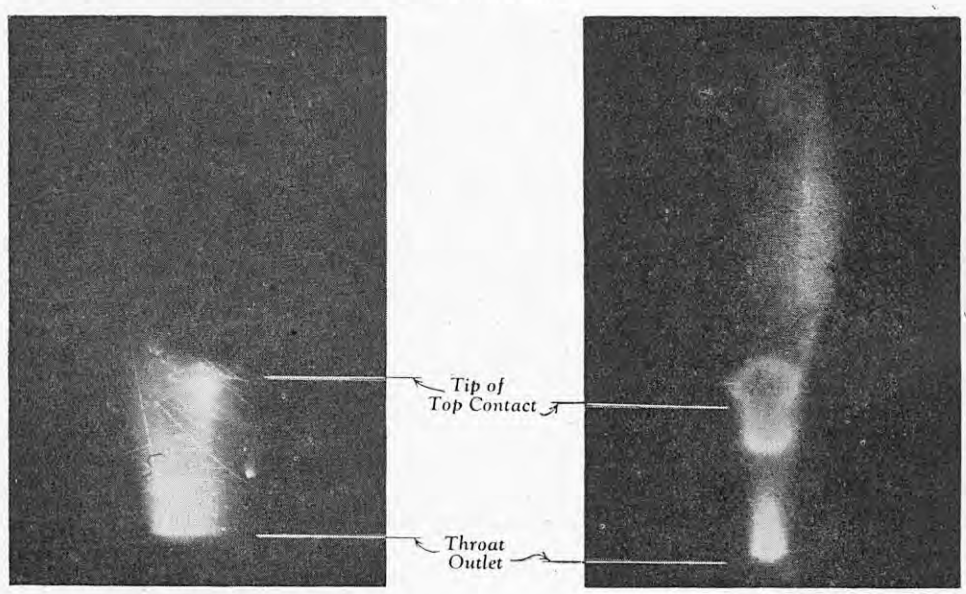
(c) 10 lb. Per Sq. In.

Fig. 12. Slit Aperture Vertical, at Different Gas Pressures.

only towards the ends of the record, as it is only during these periods that the marked changes in light intensity, occasioned by the varying height of the light cone, become opposite that level on which the slit is focused. The tailing-off of the "curtain" effect as the current approaches zero is due merely to the considerable loss in general luminosity of the arc during this period, and not to the disappearance of the flow characteristics.

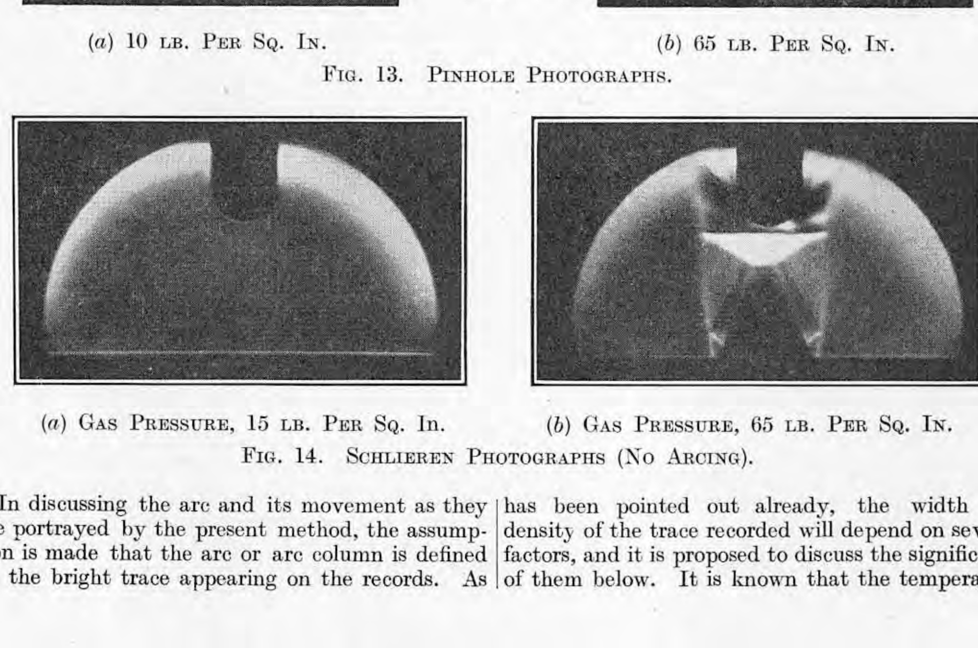
Relationship with Air-flow Characteristics.—As has already been seen from the photographs obtained with the camera slit vertical and the pinhole-camera photograph, the light intensity from the arc varies enormously over its length when the initial reservoir pressure is raised well above that necessary to obtain the velocity of sound in the throat. The intensities as shown are, of course, relative only, but there is no doubt that the arc form is modified to a large extent by the characteristics of air flow. While, however, the detailed study of air flow in a gas-blast breaker is beyond the scope of the present article, it is interesting to examine briefly the present records from this point of view. Figs. 14 (*a*) and (*b*) are "Schlieren" pictures (i.e., photographs giving patterns which are related to gas density) taken above the throat at 15 lb. and 65 lb. per square inch reservoir pressures without arcing. From Figs. 13 and 14 it will be seen that when the pressure differences—or gas density differences—are insufficient to produce a marked "Schlieren" pattern, the arc is diffused and rather shapeless.

A significant correlation has been obtained by plotting for different positions above the throat at 65 lb. per sq. in. the mean diameter over which the arc appears to have circulatory movement at current peak (for example, at A in Fig. 10 (*b*)), page 712, *ante*. The envelope for these diameters, Fig. 15, opposite, conforms reasonably well with the general shape of the arc as pictured by the pinhole camera photograph of Fig. 13 (*b*) and tends to follow the main shape of the pattern produced by the Schlieren picture of Fig. 14 (*b*). Actually, although not so obvious, this maximum movement of the arc is not confined to the current peak, and even close to zero some records show equally large transverse movement. It would, therefore, appear that the movement of the arc is confined by gas-pressure boundaries produced by the gas flow.



(a) 10 lb. Per Sq. In. (b) 65 lb. Per Sq. In.

Fig. 13. Pinhole Photographs.



(a) Gas Pressure, 15 lb. Per Sq. In. (b) Gas Pressure, 65 lb. Per Sq. In.

Fig. 14. Schlieren Photographs (No Arcing).

In discussing the arc and its movement as they are portrayed by the present method, the assumption is made that the arc or arc column is defined by the bright trace appearing on the records. As has been pointed out already, the width and density of the trace recorded will depend on several factors, and it is proposed to discuss the significance of them below. It is known that the temperature across the arc column is not uniform, being greatest at the centre and falling off as the distance from the centre increases. In general the light emitted will vary approximately in this way. Further, the wavelength of light will be characteristic of the products of arcing. Now the density of the original negative of the records depends mainly on two factors—(1) the amount of light falling on the photographic emulsion which, in turn, is controlled by the "aperture" of the optical system, including the slit width and film speed; and (2) the colour sensitivity of the emulsion in relation to the wavelength of the light being emitted from the arc. In the present recordings, the film used has its maximum sensitivity in the green-blue range and tends to accentuate light from this part of the spectrum. (This effect, as previously pointed out, is most apparent when the fuse blows at the initiation of the arc, the copper vapour produced giving strong radiation in the green.)

Limitations in photographic reproduction processes will also influence the final picture obtained and it will thus be appreciated that a change in any of the aforementioned photographic factors will give an apparent change in arc diameter. Therefore the arc as photographed herein cannot be considered as defining the arc in any detailed way. These limitations apply in general to all methods of arc photography and make any estimate of "arc diameter" from such records open to question. In addition, in the present study the rapid movement of the arc in relation to the film speed makes an estimate even more difficult. However, several attempts were made, using both types of record (i.e., with slit both vertical and horizontal) and from both geometrical considerations and photographic-density measurements to obtain an estimate of the diameter of the arc as portrayed by the luminous trace, but no reliable estimate could be made where the arc is of the filamentary form. It will be obvious, however, that the diameter during the main current flow is very much greater than that of the arc around zero. Moreover if, as has been suggested earlier, the arc is limited in its movement, then a record such as Fig. 10 (*b*) at A, in which the arc during the current peak period appears to have a small lateral movement, would seem to indicate an arc diameter almost equal to the full diameter of the trace, in this case approximately 0·5 cm.

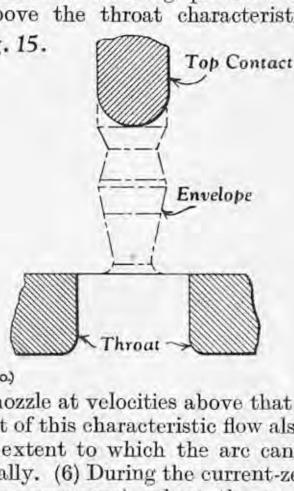
It is estimated that, with the arc moving at the speed indicated, a peripheral speed of the film (or equivalent) from five to ten times that at present used would be needed before a reasonable estimate of what might be termed "arc diameter" could be obtained. Even under these conditions it is doubtful whether the normal photographic techniques would yield results very close to current zero. One of the most interesting features of the records is the anticlockwise fast circulatory motion of the arc. The length of the arc, over that part observed, would appear roughly to trace out the surface of a hollow cylinder the axis of which is concentric with that of the top electrode and throat. However, the cause of this particular motion is not yet clear; neither is it yet known whether it has any appreciable effect on arc rupture. The effect of magnetic fields was briefly investigated as being a possible cause, because tests made on low-current arcs at the E.R.A. had shown that the arc takes on a spiral form under the influence of vertical magnetic fields; but one or two experiments made using comparatively strong magnetic fields, both vertical and horizontal, showed no marked effect on either the amplitude or frequency of motion.

The effect of air flow was also given some consideration, and the possibility of the two horizontally-opposed air inlets not being diametrically opposite, and thus causing swirling, was considered, but baffles producing uniform flow and located in the arcing chamber between the air inlets and the electrode system failed to have any appreciable effect. Even when four thin vertical copper baffles leaving a $\frac{1}{8}$ in. diameter central vertical hole were introduced into the throat, arc movement was curtailed only to a limited extent. A possible cause of the movement of the arc may be in the arc roots. It has been seen that the arc root on the top electrode has a motion similar to that of the arc as a whole and such movement, if it is present on the lower electrode (and the nature of the burn tends to substantiate this), may be the prime mover, carrying the arc column with it.

It will be seen from the above that the cause of the circulatory movement is still uncertain, and a more detailed study of this aspect will be required before its influence on the processes of arc extinction can be assessed. However, the knowledge gained of the general form and physical behaviour of the arc throughout the whole half cycle as portrayed by the present technique is obviously of much value in helping to build up the complete picture of the arc—an essential to the full understanding of the action of gas-blast circuit-breakers.

Conclusions.—Under the given conditions of test the more salient features of the results concerning that portion of the arc above the throat can be summed up as follows. (1) The arc has a diffused and indeterminate form until the gas pressure in the arcing chamber is sufficient for the velocity of sound to be attained in the throat. (2) Above this pressure the arc takes a more determinate form, and, at least during the lower values of current in the half cycle, is of a filamentary nature, having a vigorous circulatory motion, tracing out approximately the surface of a cylinder coaxial with the axis of the electrodes with a mean peripheral velocity of approximately 50,000 cm. per second. (3) The actual form and light intensity from the arc vary with the position above the throat for the conditions in (2) above. (4) This difference can be correlated with the differing pressure zones and gradients above the throat characteristic of gas

Fig. 15.



(5270)

flow from a nozzle at velocities above that of sound. (5) The effect of this characteristic flow also appears to limit the extent to which the arc can move or expand laterally. (6) During the current-zero period (at the higher pressures), where the general light intensity from the arc is very low, a short-time high-intensity discharge can usually be observed, corresponding to the arc restriking. (7) Limitations imposed by the present and other methods using the normal photographic processes and technique make an estimate of "arc diameter" open to question.

The author wishes to express his thanks to Mr. E. Whiting for his help in the experimental work which formed the basis for the present article.

THE LATE MR. J. A. ROSS.—We record with regret the death of Mr. John Alexander Ross, which occurred on November 26, after a short illness, at Woodhall Spa, Lincolnshire. Mr. Ross, who was joint managing director of Ransome and Marles Bearing Co., Ltd., Newark-on-Trent, had been associated with that firm for the past 27 years, having joined the company as secretary in 1924 after practising as a chartered accountant with Wilson Stirling and Company, Glasgow. In February, 1936, Mr. Ross relinquished the secretaryship on being appointed joint general manager. In August of the following year he was elected a director and, in October, 1941, became joint managing director.

BUILDING FOUNDATIONS AT SHREWSBURY.—In a report to the town council of Shrewsbury, Mr. F. R. Dinnis, the borough surveyor, states that a large part of the town is built over a deep bed of sand, the lower levels of which are saturated with water. In the town centre, many old buildings, and even some modern ones, show signs of settlement cracks, and, while it is not possible to prove that the settlements are due to movements in the deep sand substratum, it is probable that such is the case. The cracking of walls was a problem in 1788, when Thomas Telford was called in to advise on roof repairs at the old church of St. Chad. He found the walls badly fractured and insisted that they should be given attention. His advice was not taken and soon afterwards the building collapsed.

DEVELOPMENTS IN NOTCH-BAR TESTING.

A SYMPOSIUM on "Recent Developments in the Notch-Bar Testing of Materials and their Relation to Welded Construction," organised by the Joint Committee on Materials and their Testing in association with the Institute of Welding, was held at the Institution of Civil Engineers, London, on Wednesday, December 5. We dealt, on page 723, *ante*, with the opening proceedings and the speech made by the chairman, Professor E. C. Rollason, and we give below a report of the remarks by Dr. N. P. Allen, Superintendent, Metallurgy Division, National Physical Laboratory, Teddington, Middlesex. Dr. Allen, as *rapporteur*, presented the five papers in the symposium, and, in doing so, gave, in brief outline, the main points put forward by the authors. This report is reprinted below. The papers comprised "Notch-Bar Testing and the Selection of Steel for Welded Construction," by Mr. W. Barr, A.R.T.C., M.Inst.W., F.I.M., and Mr. I. M. Mackenzie, B.Sc., of Colvilles Limited; "The Assessment of Notch Ductility by a Variety of Notch Tests," by Mr. G. M. Boyd, M.I.N.A., A.M.I.Struct.E., M.Inst.W., of Lloyd's Register of Shipping; "The State of Stress and Brittle Fracture," by Professor W. Soete, of the University of Ghent; "Notch-Bar Tests in Relation to Service Performance," by Mrs. C. F. Tipper, M.A., Sc.D., of the University of Cambridge; and "Development of a Testing Method on Brittle Fracture of Mild-Steel Plates," by Dr. J. H. van der Veen, of the Royal Netherlands Blast Furnaces and Steelworks, Ijmuiden, Holland.

REPORT BY DR. N. P. ALLEN.

Two of the papers, Dr. Allen observed, represent the viewpoint of the maker of the steel, while the others represent the viewpoint of the user The papers are printed in the alphabetical order of the names of the authors, but it happens that this is a convenient order for presentation. The papers by Messrs. Barr and Mackenzie, Mr. Boyd and Professor Soete will be taken this morning, and those by Mrs. Tipper and Dr. van der Veen this afternoon, and this has the advantage that both viewpoints, will be presented at both sessions of the discussion.

Mr. Barr and Mr. Mackenzie present a general review of their attitude towards the problem which makes a suitable starting point for the discussion. They point out that the sensitivity of a steel to the presence of a notch is not a single physical property like, for example, the electrical resistivity, that can be completely expressed in a single figure, but is a complex result of many factors, the relative importance of which is different in different situations. The individual effects of these factors are as yet incompletely known, and the authors complain that emphasis on these uncertainties has obscured the fact that steelmakers do know how to make steels with different general levels of sensitivity. Engineers should appreciate the fact that steel inevitably has some tendency to fail in a brittle manner at notches, and should adjust their designs in relation to the general conditions of service so that this tendency is never exhibited or, alternatively, should choose a material having a capacity to resist brittle failure at notches that is adequate to meet the conditions which will be imposed. The use of material that has more resistance to brittle fracture than is required involves waste—either of alloying elements or of productive capacity—neither of which can be tolerated, while the use of a material having less resistance than is required involves risk of failure. Ideally, the required balance should be obtained by the detailed study of the behaviour of materials in service, but this takes too long, and is accompanied by the risk of failures. The function of a laboratory test is to reduce the delay and minimise the risk of disaster. For this purpose, the authors think, any test that effectively imitates the conditions of service can be a good guide, provided its results correlate sufficiently well with experience.

The authors contend that the results of notched-bar impact tests do, in fact, correlate with service experience sufficiently well, and they quote examples in support of their view. They consider that the test is the more severe the lower the temperature, the higher the speed of the deformation and the sharper the notch. A typical steel shows a type of fracture which changes from effectively ductile to effectively brittle (that is to say, from a fracture taking place by shear to one taking place by cleavage) as the conditions of test are made progressively more severe and, in practice, either the lowering of temperature or the degree of sharpness of the notch necessary to produce a cleavage fracture may be used as a measure of the quality of the steel. The authors themselves prefer to use the lowering of temperature, and they state that by the use of a test of this kind they have been able to show how the resistance of a steel to brittle fracture may be systematically altered by modifying the conditions of rolling, or by suitable deoxidation, or by the addition of manganese.

They also state that the resistance of a steel to brittle fracture is modified by the heat-treatment it receives in the neighbourhood of a weld, and that this resistance may be dangerously reduced. The phenomenon is difficult to study on account of the narrowness of the heat-affected zone of a weld, and little information is available. I have been surprised at the little reference made to this subject in the symposium papers as a whole; possibly there is a tacit agreement to solve the problems of the plate before tackling the more complex problems of the weld.

When the use of a steel is decided upon by means of the tests described, a second type of test is required for specification purposes. This second test must be simple, and it must be capable of placing the sample without ambiguity on one side or the other of an agreed dividing line. After discussing various aspects of this subject the authors suggest the following procedure. First a decision must be reached on the standard of quality needed in terms of the transition temperature range shown in a notch impact test, it being agreed that experience shows that a lower transition temperature is associated with a greater resistance to brittle fracture. If this transition range includes room temperature, a single notch impact test at room temperature will serve—for if a high impact value is obtained, near to that characteristic of the material when it breaks by shear—it will indicate that the transition range of the steel is on the whole below room temperature, whereas a low value will indicate that the transition range is on the whole above room temperature. If, on the other hand, the application of the steel is one which demands an impact transition range either wholly below or wholly above room temperature, the temperature chosen for the impact test must be within the expected transition range, and the same criteria as before will decide whether the transition range of the sample is above or below the chosen temperature. This method will serve, in my opinion, provided no special significance is accorded to intermediate values for, as Mrs. Tipper has shown in work quoted by Mr. Boyd, moderately high and moderately low values may be obtained on the same steel if the test temperature falls in the middle of the transition range. The degree of scatter in repeat results will often indicate, in case of doubt, whether the test temperature is in the middle of the transition range. Much prior preparation will be required if this procedure is to be adopted, for the transition ranges appropriate to each application will have to be agreed upon, and this has not yet been done.

The authors end their paper by considering a number of practical difficulties that would be encountered. The standard notch-bar test in British Standard specification No. 131, devised primarily for testing heat-treated alloy steels in the form of bars or forgings, needs to be reconsidered if it is to be applied to the testing of mild-steel plates, and the importance of the temperature of test must be emphasised. If the testing temperature is to be varied, a beam test may have advantages over a cantilever test. The difficulty of controlling the shape of the notch is emphasised. These changes will not be introduced without considerable effort and expense, and the authors appear to be of the opinion that the effort required to introduce a special acceptance test would be better spent by the steelmakers in further improving the quality of their steel by pursuing their traditional methods.

The paper by Mr. Boyd represents the viewpoint of the user who bears the responsibility of deciding whether the material is reasonably safe for its purpose. In doing so, he must rely heavily upon the skill and experience of the steelmaker, but his thoughts naturally turn upon a test that can be applied to the steel itself. He has therefore examined the available data on eight different tests for notch sensitivity to see whether valid correlations can be established, and has given special attention to cases in which the same material has been tested in two or more different ways. The previous attempts to do this have in his opinion been marred by a lack of appreciation of the difference between cleavage and shear fractures. The tests examined were: the Izod test, the Charpy V-notch test, the standard Charpy keyhole test, the Mesnager test, the DMVr (Austrian) test, the Schnadt test, the Tipper test, and the U.S. Navy tear test. The DMVr test resembles the Mesnager test except that the notch is 3 mm. deep instead of 2 mm. The Tipper test is a slow tensile test of a section of plate notched upon the edge. In this is recorded, as the transition temperature range, the temperature range over which the change from a fibrous shear fracture to a crystalline cleavage fracture takes place.

Before dealing with the tests in detail, Mr. Boyd points out that although the appearance of a crystalline fracture may justly be regarded as a danger sign, the percentage of crystalline areas in the fracture is not a true measure of the danger, since, in some cases, the specimen absorbs much energy by plastic deformation before a cleavage crack begins, and in other cases practically none. In a series of Izod tests carried out over a range of temperature on certain steels he finds that the energy absorbed is given by the equation

$$E = Qf + P,$$

where P is the energy required to start the fracture, f the percentage of the area which has a fibrous fracture and Q is a factor representing the energy required to extend unit area of fibrous fracture. The energy required to extend a crystalline fracture is practically nil. The object of notch-bar testing is principally to find out whether the specimen is one in which fracture will extend with a low or a high absorption of energy, and from this point of view Mr. Boyd considers that most notch-bar impact tests are made on specimens that are too small, in that the energy required to start the fracture plays too great a part in the total energy consumed. Mr. Boyd is also concerned about the difficulty of assessing the relative merits of two steels when their impact value-temperature curves cross, and, for the standard Izod test, proposes a system of "weighting" the observations at each temperature so as to obtain a "mean weighted energy" by which to compare the steels. I myself am not too happy about this procedure, and would like to know what our statistical friends think about it.

Turning now to the individual tests, the Izod test and the Charpy test, carried out on a specimen with an Izod V notch, are found not to be equivalent though they are often assumed to be so. The fractures obtained on the Charpy machine contain a larger proportion of crystalline areas, which is attributed to the higher striking velocity of the hammer in the Charpy test. No simple relationship is found to exist between the Izod test and the standard Charpy keyhole test. The relationship given for heat-treated alloy steels in B.S. No. 131 fails when applied to mild-steel plate. This suggests another direction in which this specification must be revised if the notched-bar testing of mild steel is to become common. The transition range is more strongly marked when the notch is sharp, and this suggests that if the object of the test is to find out whether the steel is above or below its transition temperature a very sharp notch should be used. Few results relating the Mesnager test to other types of test are available, but tests made with one steel on one machine, suggest that, with the shallow Mesnager notch, signs of brittleness appear at a higher temperature than with the deeper keyhole notch. The deeper DMVr notch does not reduce the energy absorbed in proportion to the reduction of the area below the notch. Although very large numbers of Schnadt tests have been made there are few published comparisons of this test with other tests made on the same steel. The Tipper notched tensile test generally gives a transition temperature rather higher than is obtained either with an Izod or Charpy keyhole test. In the U.S. Navy tear test the energy absorbed by the specimen is measured both before a crack appears at the root of the notch (pre-crack energy) and after the crack has appeared (post-crack energy). The pre-crack energy does not vary with temperature, but the post-crack energy decreases suddenly over a narrow temperature range, and it is stated in America that the temperature at which this change occurs has been found to agree with the temperature at which brittleness occurs in large-scale tests on notched ship plates 72 in. wide.

Summarising the whole of his data, Mr. Boyd concludes that no simple relationship can be established between the different notched tests; and that this conclusion was reached in 1931, and again in 1937. We shall probably have to reconcile ourselves to the fact that it is true. All the tests place steels roughly in the same order of merit, but not in detail, the exact order depending on the criteria by which the steels are judged. Mr. Boyd is of the opinion that the quest for a criterion that bears a fixed relation to service performance must be pursued. If, however, a criticism may be offered, it can be said that there are a thousand different types of service, and we may find ourselves faced with the necessity of producing a criterion for every different service. A more important point is that with which he concludes his paper—namely, that the difference between a notch-tough and a notch-brittle steel is in the way in which fracture propagates. We do not know enough about the mechanism of the propagation of a fracture, and when we know more we should be able to measure the physical properties upon which the propagation of a crack depends.

The third paper, by Professor Soete, is a description of experiments, and, fortunately, it bears directly upon the problem that Mr. Boyd wishes to see investigated. It is common ground to-day that the presence of a notch influences the type of fracture principally because it induces a state of triaxial stress in the region below the notch. A state of triaxial stress, according to its severity, suppresses deformation by shear and makes cleavage more probable. Professor Soete has therefore set out to measure the degree of triaxiality of stress induced by notches of varying degrees of sharpness when the steel is undergoing plastic deformation at various temperatures, and to compare it with the triaxiality induced by similar notches when the stresses are entirely within the elastic range. Two steels have been used for the tests—one a coarse-grained steel of low carbon content (0·06 per cent.) and rather high nitrogen content (0·011 per cent.), the other a fine-grained aluminium-treated steel with a rather higher carbon content (0·14 per cent.) and a lower, but not negligible, nitrogen content (0·007 per cent.). The triaxiality of stress in the elastic range was obtained by calculation, the methods of Neuber being preferred. The triaxiality of stress in the plastic range was obtained by recording the transverse strains throughout tensile tests on notched and unnotched specimens, and obtaining from them curves in which the mean stress at the measured section was plotted against natural strain. It is shown in the paper that the mean triaxiality ratio for the section below the notch can be calculated from these curves.

Two series of tests were conducted. In the first, one of the steels was tested at room temperature with notches of varying sharpness. It was found from the stress-strain curves that whereas, in the elastic range, the triaxiality ratios for the notches studied varied from 0·80 for the sharpest notch to 0·36 for the bluntest notch, the triaxiality ratios in the plastic range were much lower, varying from 0·30 to 0·25, and did not alter much as the deformation increased. This change was associated with the effective increase of Poisson's ratio when plastic deformation set in. The elongation of the steel decreased very markedly with increasing triaxiality ratio.

In the second series of tests both steels were tested over a range of temperature from − 60 deg. C. to + 400 deg. C. using an unnotched bar, and a bar with a very sharp notch of 0·1 mm. radius. It was concluded from the results on the plain bars that temperature did not appreciably affect the ductility, and consequently it was expected that temperature would not affect the ductility of the notched bars; but this was found not to be quite true, particularly of one steel. It was noticed, however, that temperature did affect the triaxiality of stress, in the sense that raising the temperature raised the triaxiality ratio, in one case from 0·25 at − 60 deg. C. to 0·42 at 200 deg. C. The greatest strain at fracture in both steels was associated with an intermediate triaxiality ratio of 0·31. Specimens tested below 0 deg. C. showed cleavage fractures but not those tested above that temperature.

The relation between triaxiality ratio and temperature is rather unexpected, and the metallurgist will note that one of the steels had a high nitrogen content and showed exceptional notch sensitivity at 200 to 300 deg. C. where strain age-hardening phenomena might have been expected. A repetition of the work using a material of simpler constitution would be welcomed, for the method of approach is promising.

(*To be continued.*)

Mond Nickel Fellowship Awards for 1951.—It is announced that the Mond Nickel Fellowship Committee have made three awards for 1951. One is to Mr. J. Preston, of the British Non-Ferrous Metals Research Association, for the purpose of studying, in Great Britain, the United States and Canada, specialised methods for the production and fabrication of metals, with particular reference to powder-metallurgical techniques. The second award is to Mr. P. E. White, of Messrs. J. B. and S. Lees, Limited, and is for the study of the metallurgy and detailed production technique of high-quality strip steels in the United Kingdom, Scandinavia, the United States and Canada, with particular reference to hardened and tempered steel strip, stainless steels, and silicon steels. The third award is to Mr. P. J. Hill, of the Public Works Department, Western Australia, and is for the study, in the United Kingdom, of the application of research to the development of corrosion-resistant metals for use in the mechanical engineering industry.

Slide Rule for Belt Calculations.—To enable the most efficient and economical width of belt for any particular drive to be determined without calculation or recourse to belting tables, Messrs. Lewis and Taylor, Ltd., Gripoly Mills, Cardiff, have produced an ingenious slide rule which is particularly simple to use. To find the belt required for any particular drive, it is only necessary to set the slide so that the appropriate indications of driving-pulley diameter and revolutions per minute coincide. The belt speed and the width of belt required to transmit any given horse-power may then be read off on other scales. In design work, the diameter and speed of the driven pulley can also be determined without further setting of the rule. A table engraved on the instrument gives recommended minimum pulley diameters for various thicknesses and types of belting. Widths and thicknesses are given for solid woven-hair belting, rubber and canvas ply belting and belting woven from elastic yarn, all as manufactured by Messrs. Lewis and Taylor. The instrument is of transparent plastic and may be obtained gratis by approved applicants.

THE PRODUCTION OF SMALL INTERNAL-COMBUSTION ENGINES.

PETTERS LIMITED, STAINES, MIDDLESEX.

FIG. 1. 19-H.P. FOUR-CYLINDER V-TYPE PETROL ENGINE.

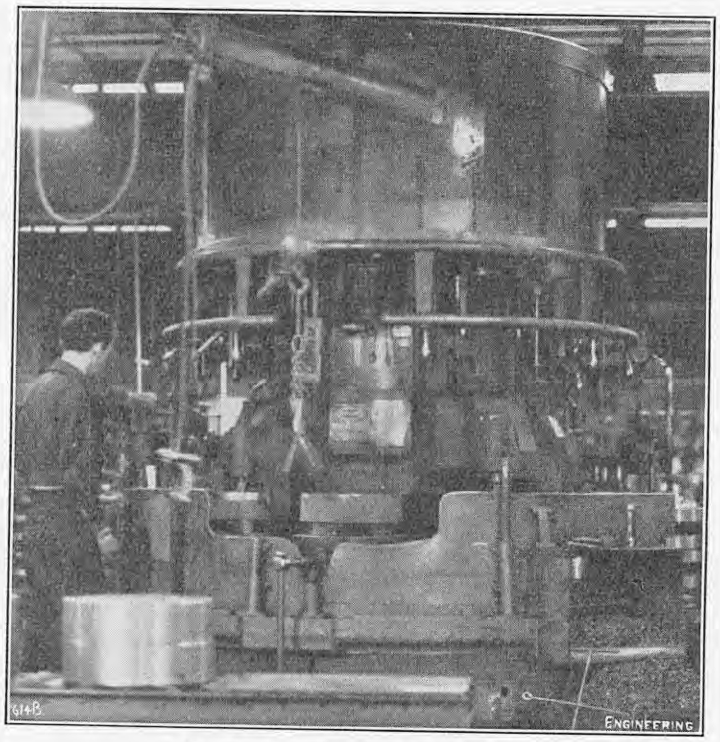


FIG. 2. MACHINING FLYWHEELS.

THE CAUSEWAY WORKS OF PETTERS, LIMITED AT STAINES.

PETTERS, LIMITED, the small-engines division of the Brush-Associated British Oil Engines Group, originated in Yeovil, where their first paraffin-oil engine was produced in 1895. From this date until the outbreak of war in 1914, they continued to produce paraffin engines, mainly for use on farms and in agricultural machinery, but during the first World War they were concerned with the manufacture of aircraft and were the original Westland aircraft works. At the end of the war, they returned to full production of engines, the aircraft side of the business being taken over by a separate company in which, for a time, they retained an interest. When the business was absorbed into the Brush-Associated British Oil Engines ("Brush-Aboe") Group in 1938, it was decided to dispose of the Yeovil works and transfer the production of Petter engines to the Loughborough works of the Brush Electrical Engineering Company, Limited. In view, however, of the constantly rising demand, particularly for the smaller engines, it soon became apparent that separate premises would be required for their manufacture. Accordingly, in 1944, the Group acquired the Staines factory of Lagonda, Limited, manufacturers of the Lagonda car, which has since been reconstructed and laid out for the production of the lower horse-power Petter oil and petrol engines. Actual production of the engines was not fully started until 1948.

Production of engines at the Staines factory has increased steadily since its inception, and so far this year the rate has averaged 1,500 engines a week. All of the existing range of engines have been developed since the war; they include air-cooled and water-cooled petrol and paraffin engines of $1\frac{1}{2}$ h.p. to 10-h.p., together with the more recent "AV" series of 3-h.p. to 10-h.p. Diesel engines. Recently, their range of petrol engines was added to with the introduction of the four-cylinder V-type unit illustrated in Fig. 1, on this page. Known as the PAV4, it is designed to develop 19 brake horse-power on the B.S. 12-hour rating with a momentary overload of 10 per cent. Its bore and stroke are 85 mm. and 82·5 mm., respectively, and it is conservatively rated at 66 lb. per square inch brake mean effective pressure with a piston speed of 1,083 ft. per minute. It has been designed to take its place in the flow of production normally associated with the Staines factory, and for this reason as many parts as possible have been made so that they are interchangeable with existing petrol-engine models. Cylinders, cylinder heads, pistons, gudgeon pins, valves and valve springs, for example, are completely interchangeable. The question of interchangeability, which applies equally to Diesel engines, has received careful and constant attention, and is one of the factors that has enabled the works to maintain such a high rate of production and yet manufacture engines of different outputs.

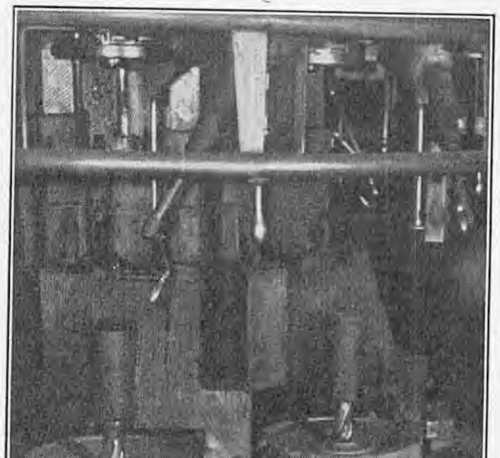


FIG. 3. TOOL SET-UP ON FLYWHEEL MACHINE.

Extensive modifications have been made to the Causeway works since it was taken over four years ago and the factory may be considered as almost having been reconstructed. It comprises a series of modern buildings covering an area of approximately 220,000 sq. ft. and laid out to produce six types of engine simultaneously. The machine shop, which covers 30,000 sq. ft., is equipped with a wide range of modern machine tools and is arranged so that the larger components travel down eight main machine lines, smaller parts being dealt with in batches by groups of machines. Much use is made of special equipment either adapted from standard machine tools or built for a particular purpose. By using a standard drilling machine, for example, it has proved possible to drill all the holes in a cylinder head by modifying it to carry 17 spindles. A good example of a machine designed for a special purpose is that illustrated in Fig. 2, on this page, which has been installed for machining flywheels. It has eight stations, each of which, with the exception of the loading station, is provided with a tool set-up designed for a particular operation; some of the tool positions are illustrated in Fig. 3, on this page. The tools are fed down vertically towards the flywheels, which are moved progressively to each station by mounting them in rotating chucks installed on a horizontal circular table, the table being indexed an eighth of a turn each time the tools are withdrawn. Another special-purpose machine tool is illustrated in Fig. 4, on page 752; this is used for drilling the crankcases and was designed and constructed by the Brush Electrical Engineering Company, Limited. Other special-purpose machines include a crank-case borer.

The machine shop is laid out so that all parts converge through the deburring and washing sections to final inspection and the finished-part stores from which they are issued to the assembly shop. At present, the assembly shop is being re-organised so that eventually all the parts for a complete engine can be carried by trays down a power-driven conveyor and the engine assembled as it moves along. The power-driven conveyors are already in use but, for the present, the parts are being supplied from bays disposed at each side. Crankcases are fed to the conveyor at given intervals by means of the trip-feed mechanism illustrated in Fig. 5, on page 752, which is controlled by buttons from the conveyor chain. There are two control valves arranged so that when the first is depressed by the conveyor button, a brake is released from the front rollers and an end-stop disengaged. The first crankcase then gravitates on to the conveyor forks and is picked up by the moving slats. The second valve is then operated, causing the end stop to return into position and release the brake from the rear rollers, thus permitting the succeeding crankcases to move forward ready for the next discharge to the conveyor. It will be clear that, with this method, the supply of crankcases and, therefore, the building-time cycle, is regulated by the speed of the main conveyor. Assembly of the various parts is accelerated by using mechanical aids, such as pneumatic impact wrenches and special tools. The timing gear, for example, is assembled on the crankshaft by means of the floating press illustrated in Fig. 6, on page 752, which is lowered into position by a small hoist and anchored to each end of the crankshaft. A hydraulic cylinder actuated by a pneumatic booster is mounted at the opposite end to the timing gear and exerts a pressure of 6 tons against the shaft; thus the gear is drawn into position on the shaft by the movement of the yoke.

On leaving the assembly line, all engines, regardless of the type, pass into the test house, where they are run under their own power for one to one and a half hours, the last 15 minutes at 20 per cent. overload. The test house has 50 test beds, some of which are equipped with dynamometers of a new type designed so that their impellers can rotate in either direction. To leave clear working areas, all services such as water, fuel and lubricating-oil lines, have been placed below floor level in covered ducts. This arrangement gives a clean and neat layout, as will be evident from a study of the photograph of the test house reproduced in Fig. 7, on page 752.

DOUBLE-HEADED MILLING MACHINE FOR LOCOMOTIVE FRAMES.

CRAVEN BROTHERS (MANCHESTER), LIMITED, REDDISH, STOCKPORT.

FIG. 1. MACHINE IN MAKERS' WORKS.

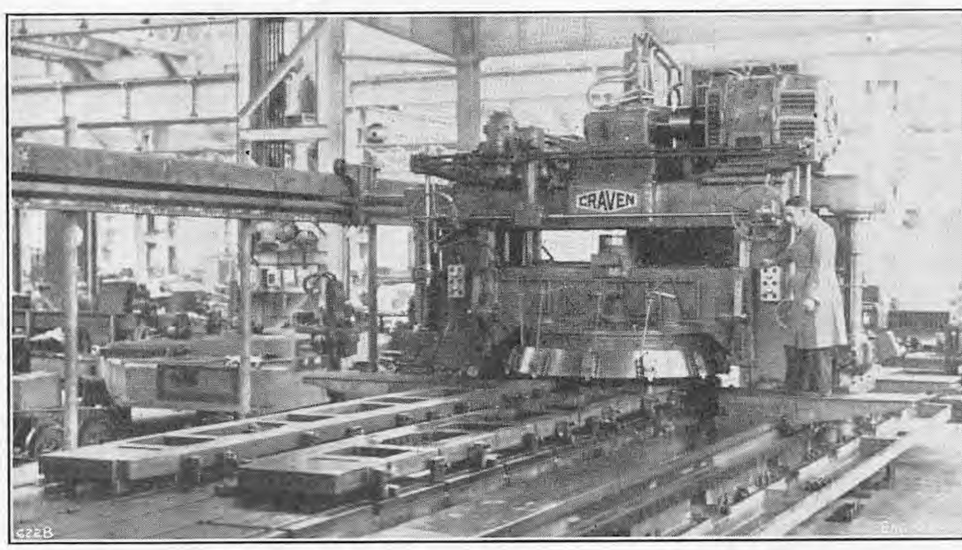


FIG. 2. USING ONE MILLING CUTTER ON FRAME SLABS.

DOUBLE-HEADED MILLING MACHINE FOR LOCOMOTIVE FRAMES.

THE large milling machine shown in Fig. 1, herewith, has been built by Messrs. Craven Brothers (Manchester), Limited, Reddish, Stockport, for machining the faces of locomotive frames of the bar type. It has been dispatched recently to the Chittaranjan locomotive works of the Indian Government Railways, where it will be used in conjunction with a Craven triple-headed slotting machine for locomotive frames. The frame slabs are up to 50 ft. long, 6 ft. wide and about 5 to 6 in. thick. As will be seen from Fig. 1, the machine is equipped with two large milling cutters running on vertical spindles; there are also two smaller, auxiliary milling heads for machining holes and small radii, or for cross-milling work.

The machine comprises a heavy baseplate, 70 ft. long by approximately 11 ft. 3 in. wide, and two bridge-type machine units. The central portion of the baseplate, 6 ft. 9 in. wide, is arranged as a workplate and is provided with T-slots and dog holes for locating and clamping the frame plates in position, as shown in Fig. 2. Outer slideways along each side of the workplate carry the two travelling machine units. The baseplate is fitted with foundation bolts and levelling screws, and is constructed in three sections securely bolted and keyed together. The framing of each machine unit consists of two massive uprights which are mounted on separate base saddles and are tied together at the top by a deep-section cross-stay to form a rigid bridge-type construction. The main milling head is centrally housed in an adjustable cross-beam supported between broad slideways, forming the inner faces of the uprights. A cross-slide, integral with the rear of the cross-beam, carries the auxiliary milling head, and the whole beam assembly has both fine hand-operated vertical adjustment and rapid power elevation for setting purposes and for the application of the cutters to the work. Powerful clamping devices lock the beam to the uprights during cutting.

Both machine units are of identical construction. In each case the main cutter head is 6 ft. 9 in. in diameter, and comprises a circular cast-iron body to the periphery of which are secured 12 steel tool-blocks. Equally spaced around the body, the tool-blocks are fitted with adjustable square-section cutting tools, so that the whole assembly constitutes a giant inserted-tooth face-milling cutter. The cutter head is carried on a vertical spindle rotating in plain phosphor-bronze bearings, and is also supported by an inverted V-type circular bearing track, white-metal lined, which absorbs all the resultant cutting thrust. Screwed collars and a large ball-thrust washer withstand the load of the spindle and cutter head in a vertical direction.

Cutter speeds range from 1½ to 6 r.p.m., the drive being by means of a 25-h.p. variable-speed reversing motor mounted on the top of the cross-stay. The transmission is through a primary wormgear reduction unit and a vertical splined shaft to intermediate gearing in the cross-beam, the final drive being by dual pinions in mesh with a large-diameter internal spur ring secured to the body of the cutter head. The maximum and minimum heights available beneath the main cutting head are 15 in. and 5 in., respectively, vertical movement being effected through two elevating screws adjacent to the inside faces of the uprights. Fine adjustment is provided by two handwheels conveniently situated at each side of the unit, one revolution of the handwheels corresponding to 0·02 in. movement of the cutter head. Quick power operation is provided by a 10-h.p. constant-speed reversing motor mounted on the cross-stay, the rate of power elevation being approximately 12 in. per minute.

There are six longitudinal milling feeds, ranging from 0·28 to 2·8 in. per minute. These are obtained by the power traverse of the whole machine unit along the baseplate slideways, and are thus applicable both to the main and auxiliary milling heads. The feed drive is obtained from a separate 3-h.p. constant-speed reversing motor and feed-change gearbox mounted on the cross-stay. It is conveyed by spiral-bevel gearing and vertical shafts at the side of the uprights down to further reduction gear units on the base saddles. Finally, two pairs of pinions engage racks attached to the front and rear of the baseplate, as shown in Fig. 3. Each pair of pinions has special provision for the elimination of backlash, and the two pairs of pinions are coupled together to drive in unison. Rapid power traverse is transmitted through the same mechanism, but is derived from the 10-h.p. elevating motor. Selection for longitudinal feed or quick traverse, and for hand or power elevation of the cross-beam, is made by duplicate sets of hand levers mounted at a convenient height one on the side of each upright.

Mounted on its own saddle, the self-contained auxiliary milling head, shown in Fig. 4, is fitted to a cross-slide at the rear of the cross-beam. The vertical spindle rotates on roller and angular-contact bearings and is bored and recessed to suit standard milling cutters and adaptors. Spindle speeds range from 12 to 98 r.p.m., and the drive is by an independent 10-h.p. constant-speed reversing motor and an eight-speed gearbox. The spindle slide is carried in V slideways and has a 21-in. vertical adjustment relative to the cross beam for cutter setting or hand feed. The lower face of the slide has circular T-slots suitable either for attaching outer milling-arbor supports or for fitting a special horizontal milling-spindle attachment, should the need arise. Transverse feed and quick power traverse of the auxiliary milling head along the cross-slide is provided by a separate 3-h.p. constant-speed

DOUBLE-HEADED MILLING MACHINE FOR LOCOMOTIVE FRAMES.

CRAVEN BROTHERS (MANCHESTER), LIMITED, REDDISH, STOCKPORT.

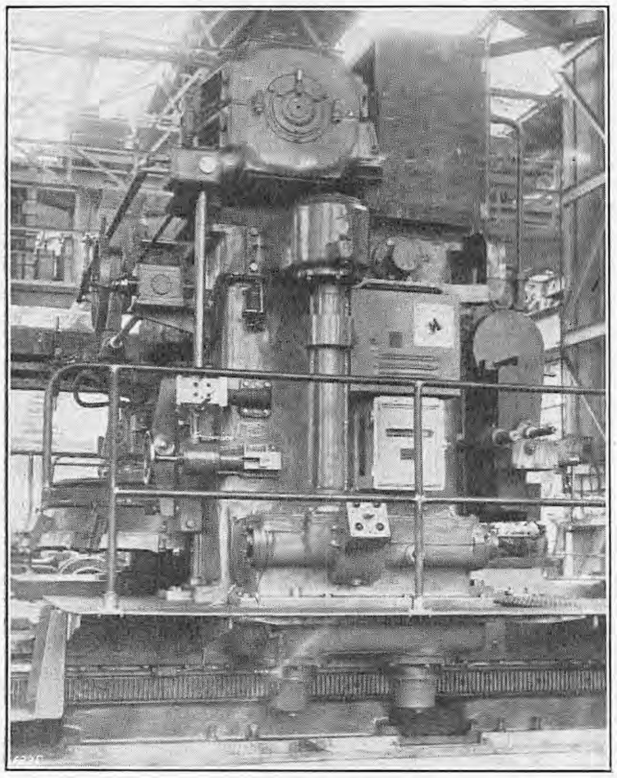


FIG. 3. SIDE OF ONE MACHINE UNIT, SHOWING DRIVE FOR LONGITUDINAL FEED.

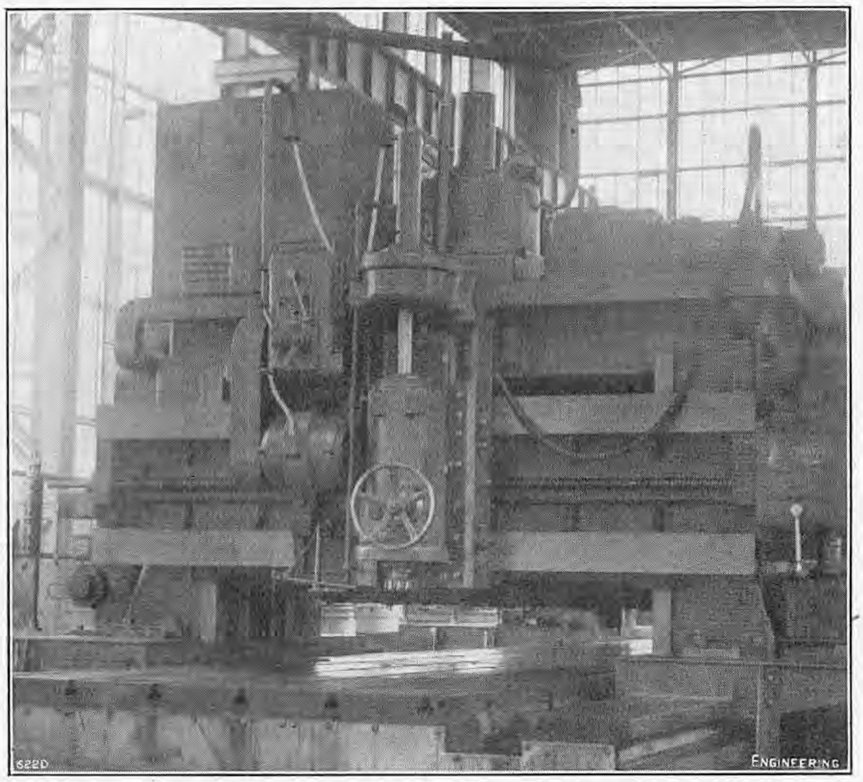


FIG. 4. AUXILIARY MILLING HEAD.

reversing motor and a feed-change gearbox at the end of the slide. There are six rates of transverse feed, ranging from 0·5 to 4 in. per minute, and the extent of the transverse travel is approximately 7 ft. 5 in., so that the full width of the work-plate is amply covered by the auxiliary cutters.

The machine is arranged to operate from 400-volt 3-phase 50-cycle mains supply, a motor-generator set, controlled by an auto-transformer starter, being used to supply direct current for the two 25-h.p. variable-speed main milling-head motors. All the remaining motors on the machine operate from the alternating-current supply. Both the alternating and direct current is fed to the machine by means of supply bars mounted on an elevated gantry and collector shoes attached to each machine unit. A main control panel, on the cross-stay of each unit, houses the switchgear for the main milling-head motor and the 10-h.p. elevating and quick-traverse motor. Smaller panels attached to the uprights control the two 3-h.p. feed motors and the 10-h.p. auxiliary milling-head driving motor. Separate speed regulators are provided for each main variable-speed motor.

Identical push-button stations on the front of each upright control the main milling-spindle motor and the longitudinal-feed motor, and include "forward" and "reverse" inching buttons for the elevating and quick power-traverse motor. Additional stations at the rear of the uprights include further push-buttons for the elevating and quick-traverse motor, together with controls for the suds-pump unit. A large pendent-type station at the rear of each machine unit contains push-buttons for the control of the auxiliary milling head and its transverse-feed and quick-traverse motor, also duplicate controls for the longitudinal-feed motor and for the elevating and longitudinal quick-traverse motor.

A feed-selector switch, mounted on one of the smaller control panels, has four positions to allow for the following: milling with the main cutter head, using the longitudinal feed; milling with both spindles and longitudinal feed; milling with the auxiliary spindle and longitudinal feed; and milling with the auxiliary spindle in conjunction with the transverse feed. In each instance it is impossible to start the particular feed motor until the appropriate milling spindle is running, and, if the spindle motor stops, then the feed motor will also stop. The longitudinal quick power traverse and elevating motor can be used with the selector switch in any of its four positions, and a "test" push-button in the pendent control station enables the transverse-feed and quick-traverse motor to run for setting purposes with the auxiliary milling-spindle motor at rest.

PLANT FOR PRODUCING CATALYTIC CRACKING AGENT.

REMARKABLE progress has been made during recent years in the development of oil-refining processes, one of the outstanding features being the introduction of fluid catalytic cracking. In this process, cracking is carried out in the presence of catalysts consisting of clays and related solid synthetic materials, the result being that the process can be operated at lower pressures and temperatures with better overall yields and improved products. Until recently, this process was confined largely to overseas refineries and there was, therefore, little demand for the catalyst in this country. The opening of the new Esso refinery at Fawley, with its catalytic-cracking plant, and the installation of a similar plant at the Shell refinery, Stanlow, to mention only two, has led to lively home demands and, to meet these, Messrs. Joseph Crosfield and Sons, Limited, Warrington, an associated company of Messrs. Lever Brothers and Unilever, Limited, Unilever House, London, E.C.4, have erected a plant for the manufacture of a suitable catalyst. The plant was built as a result of agreements between Messrs. Crosfield and the Davison Chemical Corporation of Baltimore, U.S.A., and between Messrs. Crosfield and the Esso Petroleum Company, Limited, the Anglo-Iranian Oil Company, Limited, the Shell Refinery and Marketing Company, Limited, Trinidad Leaseholds, Limited, and the Bahrein Petroleum Company, Limited. Messrs. Crosfield were in a strong position to take up this work as the main raw material used in the manufacture of the catalysts is sodium silicate, of which the firm are the major producers in the United Kingdom.

Technical advice on the design, construction and operation of the plant has been provided by the Davison Chemical Corporation, the leading catalyst manufacturers in America, whose process is to be used. Design work on the Warrington plant was begun in March, 1950, and clearance of the site in June of the same year. Constructional work was started under the direction of Messrs. E. B. Badger and Sons (Great Britain), Limited, in October, 1950, the main contractors being Messrs. Taylor Woodrow Construction, Limited. With a few exceptions, the plant has been constructed and equipped with materials of British manufacture, but some items had to be obtained from the United States. The equipment includes two stainless-steel driers fabricated in this country under licence from the Swenson Evaporator Company, which are the largest of their type to have been built. The plant was opened by Sir Geoffrey Heyworth, chairman of Lever Brothers and Unilever, Limited, on December 4.

BOILER EXPLOSION AT GUILDFORD POWER STATION.

As a result of an explosion from a water-tube boiler at the Guildford power station of the British Electricity Authority on May 7, 1951, a preliminary inquiry under the Boiler Explosions Acts, 1882 and 1890, has been held and a report* has been issued recently. The boiler, one of a bank of three, was of the Stirling three-drum type and was about 24 years old. The drums were 3 ft. 6 in. in diameter internally and 19 ft. 9½ in. long, the steam drums being connected to the water drum by 495 solid-drawn steel tubes of 3¼ in. outside diameter, arranged in two banks.

The explosion occurred from the extreme left-hand tube in the second row of the front bank, the tube rupturing at about the middle of its length and forming an opening 7½ in. long and of 5½ in. maximum width, through which the contents of the boiler escaped into the furnace, with fatal results, the shift charge engineer being killed and two other station employees seriously injured. The cause of the explosion was overheating due to deposits of hard scale.

The boilers were connected to a common range and supplied steam at 295 lb. per sq. in. to four turbo-alternators. Before the station was taken over by the British Electricity Authority in 1948, the make-up feed consisted of river water without treatment, though a linseed filtrator was fitted in 1944. Since 1949, however, evaporated town-main water had been used for feed make-up, with the addition of some town-main water chemically treated in accordance with instructions issued by the B.E.A. Examination of the tube after the explosion showed traces of hard scale from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. in thickness on the inner surface near the rupture, and the tube, as the result of overheating, had swelled about 1 in. circumferentially at the burst. In course of the examination it appeared that a fairly heavy hard scale formed in the tubes until the linseed filtrator was introduced in 1944, when there was a considerable reduction in the quantity and hardness of the scale formed. Since the introduction of the chemically-treated feed, only a soft sludge had been found, apart from the old hard scale which was gradually disappearing. In his concluding remarks, Mr. F. J. Colvill, Assistant Secretary, Marine Safety Division, Ministry of Transport, points out that trouble had been experienced with tubes over a period of years and it had been found necessary to renew a number of them owing to blistering and swelling, but the cause of the trouble, apparently, had not been fully investigated.

* H.M. Stationery Office. [Price 1s. net.]

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

THE LATE MR. J. H. DINWOODIE.—It is with regret that we record the death, on November 28, of Mr. John Henderson Dinwoodie, manager of the Edinburgh branch of British Insulated Callender's Cables, Ltd. He was 50 years of age and had joined the former firm of Callender's Cable and Construction Co., Ltd., in 1916. Subsequently, he served for many years in the company's Glasgow office where he specialised in mining electrification work.

PROPOSED BRIDGE OVER THE CLYDE.—A proposal to construct a bridge over the River Clyde in the inner area of Glasgow was discussed on December 4 by a sub-committee of Glasgow Corporation and representatives of the Clyde Trust. As an alternative to a bridge, the possibility of a tunnel under the river was also examined. It was stated that, if a bridge proved to be the acceptable solution of the problem, it would be of the opening type, to give free passage to shipping.

GLEN FINGLAS WATER-SUPPLY SCHEME.—The development of Glen Finglas as a new source of water supply for Glasgow was approved by the Water Committee of Glasgow Corporation on December 4. The project, estimated to cost 600,000*l*. and to provide 7,333,000 gallons a day, entails the construction of an intake weir and the driving of a 2½-mile tunnel through the shoulder of Ben An to Loch Katrine. Only a small dam will be formed at the weir, so that there will be no extensive flooding of Glen Finglas and no sacrifice of agricultural land.

TOWN PLANNING IN GLASGOW.—Glasgow's development plan was finally approved on December 6 by the City Corporation. The plan has two main aspects—the mapping of arterial roads, including an outer ring road, and the zoning of the whole city area for industrial, commercial, and residential purposes, thus setting the pattern for future development. The Corporation's concern is to ensure, by the preparation of the plan, that the best possible use shall be made of available land and that the haphazard mingling of places where people live and where they work shall be prevented.

THE P.S. "LUCY ASHTON."—The former paddle-steamer Lucy Ashton, which plied on the Clyde for about 60 years, is to be broken up at Faslane. The vessel was built in 1888 by the firm of T. B. Seath, Rutherglen, now out of existence. Nearly three years ago the hull was purchased by the British Shipbuilding Research Association and fitted with four aircraft jet engines, for the purpose of carrying out experiments on hull resistance. Particulars of the vessel, as thus converted, were given in our issue of August 18, 1950 (vol. 170, page 161).

FACTORY TO BE BUILT IN KIP VALLEY.—An area of 110 acres in the Kip Valley, between Greenock and Inverkip, has been acquired from Ardgowan Estates, Ltd., as a site for a new factory for the American firm of International Business Machines (United Kingdom), Ltd. The factory itself will occupy about 30 acres and will be built by Scottish Industrial Estates, Ltd.

VEHICULAR TRAFFIC ON FORTH BRIDGE.—If the Forth Bridge were converted to carry vehicular traffic above the existing railway track its appearance would be improved rather than otherwise, according to Sir Bruce White, M.I.C.E. Sir Bruce, who was addressing the Scottish branch of the Institution of Highway Engineers on November 30, in Edinburgh, said that the roadway could be built of light alloys of the aluminium-magnesium-silicon type.

LOSS OF BATTLESHIP "SAO PAULO."—After having abandoned her search for the former Argentine battleship Sao Paulo, lost in the Atlantic, the Metal Industries tug Bustler returned to her base in the Gareloch on December 1. The Bustler, with another tug, the Dexterous, was towing the Sao Paulo from Rio de Janeiro to the Clyde for breaking up when the tow ropes parted during heavy gales. One of the crew of the Bustler was lost overboard on the return voyage.

CLEVELAND AND THE NORTHERN COUNTIES.

EXPORT OF MOTOR CARS TO WEST AFRICA.—At Middlesbrough Docks, last week, 300 motor cars and a river launch were loaded on board the Elder Dempster liner Freetown for shipment to West Africa. Normally there is not a big trade between the Tees and West Africa; this, however, is the second cargo of motor cars to go to that destination in the past month. The Freetown also took on board 3,000 tons of general cargo, and the hope is expressed that a considerable trade may be established between Tees-side and West Africa.

OBJECTIONS TO EXTENSION OF OUSEBURN SEWER.—Speaking at a public inquiry held at the Town Hall, Newcastle-upon-Tyne, on December 4, to hear an objection to the Corporation of Newcastle's scheme to extend the Ouseburn Sewer westward, at an estimated cost of 68,000*l*., Mr. C. R. Ward, for the Corporation, said that they did not accept the contention that, if the proposal were carried into effect, it would increase the pollution of the River Tyne; the increase, in fact, would be infinitesimal. The main purpose of the plan, he stated, was to serve the projected Corporation housing schemes of Kenton and Fawdon. The objection had been raised by the Northumberland and Tyneside River Board, and Mr. N. H. Thomas, Clerk to the Board, contended that the proposed sewer would increase considerably the already serious pollution of the Tyne. The Board felt that the proposed extension and other new sewers should be designed and sited in such a manner as to form part of a comprehensive scheme of sewerage and sewage disposal. Mr. Ward, in reply, said that the Corporation felt that any such comprehensive scheme for dealing with pollution could not well be carried out by local authorities unaided.

APPEAL BY STREET-LIGHTING AUTHORITIES.—At a meeting in Newcastle-upon-Tyne, on December 4, the Northern Gas Consultative Council received a deputation from 14 local authorities headed by the Town Clerk of Stockton-on-Tees, requesting that street-lighting charges be made on an industrial basis. It appears that, at present, each street lamp is regarded as a separate "consumer" and the deputation's claim was that street-lighting authorities should be placed in the same category as other large consumers of gas and be granted a rebate under the Northern Gas Board's tariff.

LANCASHIRE AND SOUTH YORKSHIRE.

THE LATE MAJOR V. TURNER, O.B.E.—We learn with regret that Major Vincent Turner, O.B.E., who was borough engineer of Rotherham from 1921 to 1946, died in hospital at Liverpool on November 30, at the age of 73. He had been living in retirement at Gobowen, near Oswestry, Shropshire. He was born at Bristol, took up his Rotherham appointment in 1921, and, between the war years, was responsible for all the town engineering developments. He was chairman of the Yorkshire Association of the Institution of Civil Engineers from 1935 to 1946.

SHEFFIELD FIRM'S APPRENTICE-TRAINING SCHEME.—As a result of the introduction of education and training schemes the number of apprentices and young operatives at the Sheffield works of the English Steel Corporation, Ltd., have been raised from 300 in 1947 to over 400 in 1951. Money prizes have just been distributed to 230 apprentices and junior members of the staff to the value of 1,060*l*., in sums varying between 2*l*. 10*s*. and 11*l*. 10*s*. Mr. W. D. Pugh, a director of the English Steel Corporation, and chairman of the works education and training committee, stated, in his report, that their main efforts have been concentrated on the training of engineering apprentices. The firm are now paying attention to the training of junior operators, melters, rollers and foremen, and to preparing schemes for open-hearth and electric steel melting and rolling and forging. These schemes are being developed on lines similar to those for craft apprentices, but are complicated by the team method of working in the hot shops and problems of promotion by seniority.

EFFECT OF STEEL SHORTAGE.—In an official report to the Regional Board of Industry it is stated that steel manufacturers in the Sheffield area find themselves completely unable to consider new business in any circumstances. It is added that there appears to be no sign of easement in the scrap shortage and there are marked signs of a decline in steel production. The Board observe that another trend created by the shortage of materials is that firms are becoming more reluctant to explore overseas markets.

HIGHER COAL PRODUCTION.—Yorkshire collieries, for the third week in succession, have raised more than a million tons. At Brodsworth Main, South Yorkshire, the distinction has been achieved of being the first colliery in the country to raise a million tons this year, three weeks earlier than last year. Opencast-coal production has been impeded by bad weather and by the flooding of some sites, and this will make it impossible to reach the opencast production target this year.

TRENT VALLEY COALFIELD.—The Minister of Housing and Local Government has sanctioned the proposal of the National Coal Board to mine coal in an area of 7,000 acres in the Trent Valley, between West Bridgford and Gunthorpe. Local authorities and private business interests opposed the proposal at a six-day inquiry on the ground of the risk of subsidence and the accompanying flooding dangers. A condition has been imposed that a pillar of support shall be left under the Nottingham Corporation's main outfall sewer, which crosses the surface of the area to be worked. It is estimated that the new area will yield 21,000,000 tons of coal.

THE MIDLANDS.

JUNIOR SAFETY GROUP.—The first junior safety group in Great Britain was formed at a meeting in Birmingham on December 4. It is intended for young industrial employees between the ages of 16 and 21, and is entitled the Junior Birmingham and District Safety Group. Mr. W. W. Foster, general works manager at Fort Dunlop, and chairman of the Birmingham and District Safety Group, opened the meeting and read a message from the Lord Mayor of Birmingham (Alderman R. C. Yates), who has accepted the presidency of the group.

THE STUDY OF INCENTIVES.—Dr. W. Baldamus, Research Fellow at Birmingham University, recently concluded a study of industrial incentives, and his work has now been published, in a limited edition (price 15*s*.), under the title of *Incentives and Work Analysis*, by the Research Board of the Faculty of Commerce and Social Science at the University, Edgbaston, Birmingham, 15.

CIVIL DEFENCE SCIENTIFIC ADVISORS.—Three honorary scientific advisors have been appointed for the Midland civil defence region. All are professors at the University of Birmingham. They are Professor H. W. Melville, Mason Professor and head of the Department of Chemistry (senior advisor); Professor P. B. Moon, Poynting Professor and head of the Department of Physics; and Professor J. R. Squire, Leith Professor and director of the Department of Pathology.

PROPOSED BOREHOLE NEAR WOLVERHAMPTON.—The West Midlands Coal Board are to apply to the High Court for powers to sink a borehole at Penn, Wolverhampton, to prove reserves of coal to the north of the existing Baggeridge colliery. Penn is a residential and agricultural district, and Wolverhampton town council refused last month to grant permission for the borehole to be made. The Coal Board's intention is, if the coal is proved, to deepen the existing shafts at Baggeridge, and drive the workings northwards. Objections were raised on the grounds of possible subsidence, but the Board state that subsidence would be minimised by solid stowing of the worked-out parts of the seam.

SOUTH-WEST ENGLAND AND SOUTH WALES.

ROADS IN GLAMORGAN.—Provisional schemes for new and improved county and trunk roads in the central area of Glamorgan involve a total estimated expenditure of 6,000,000*l*. over the next 20 years, of which about 4,000,000*l*. relates to the period up to 1956. Listed for high priority, in the event of authorisation in the period up to 1956, is a 2,000,000*l*. scheme for a Port Talbot by-pass, while another, costing 1,000,000*l*., provides for the completion of the Neath by-pass. The completion of the Neath River bridge, already under construction, is estimated to cost 500,000*l*.

CARDIFF-PENARTH TOLL ROAD.—Following years of negotiations, Cardiff Corporation and Glamorgan County Council hope to take over the joint control of the Penarth toll-road connecting Cardiff and Penarth, on January 1. The Cardiff City treasurer has been authorised to pay the purchase price of 12,500*l*., with 1,500*l*. for other purposes, to the present proprietors. The City Council will continue to charge tolls until the outlay has been recovered. The Corporation has been given the power to charge tolls for a period of three years. Gross annual takings have been estimated at between 11,000*l*. and 17,000*l*., with a net income of between 2,000*l*. and 7,000*l*. a year.

WEST WALES STEELWORKS DIFFICULTIES.—The temporary shortage of pig iron caused a stoppage at ten of the 27 open-hearth furnaces of Richard Thomas and Baldwins, Limited, in West Wales last week. The arrival of three cargoes at Swansea, however, eased the situation and, by the end of the week, it had proved possible to resume smelting at five of the furnaces, while others were expected to be working again within a few days. The opportunity has been taken of carrying out repairs at some of the furnaces.

INFLUENCE OF SHORTAGE OF SCRAP.—Speaking at a luncheon at the works of the Steel Company of Wales, on December 7, Mr. E. Julian Pode, the managing director, disclosed that production at the Abbey Steelworks, at Margam, has been slowed down to two-thirds of the normal on account of the shortage of scrap.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF PACKAGING.—*Midland Area:* Monday, December 17, 12.30 p.m., White House Restaurant, Birmingham. Luncheon Meeting. "Packaging for the Services," by Mr. P. A. Andrew.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Radio Section:* Monday, December 17, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "What Practical Benefits Can Communication Engineers Expect from the Modern Information Theory?" by Mr. E. C. Cherry. *South Midland Centre:* Tuesday, December 18, 6 p.m., Town Hall, Birmingham. Faraday Lecture on "Sound Recording: Home, Professional, Industrial and Scientific Applications," by Dr. G. F. Dutton. *Supply Section:* Wednesday, December 19, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. (i) "Inhibited Transformer Oil," by Mr. W. R. Stoker and Mr. C. N. Thompson. (ii) "The Stability of Oil in Transformers," by Mr. P. W. L. Gossling and Mr. L. H. Welch. *Southern Centre:* Wednesday, December 19, 6.30 p.m., The Technical College, Brighton. "Electricity in a Chemical Works," by Mr. W. A. Gallon. *East Midland Centre:* Wednesday, December 19, 7.15 p.m., De Montford Hall, Leicester. Faraday Lecture on "Sound Recording: Home, Professional, Industrial and Scientific Applications," by Dr. G. F. Dutton. *Mersey and North Wales Centre:* Monday, January 7, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. "Modern Developments in Electric Welding," by Dr. H. G. Taylor.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Monday, December 17, 6.15 p.m., Mining Institute, Newcastle-upon-Tyne. "Marine Propulsion Miscellany," by Dr. E. V. Telfer.

INSTITUTION OF MECHANICAL ENGINEERS.—*East Midlands Branch:* Monday, December 17, 6.30 p.m., Offices of East Midlands Gas Board, Parliament-street, Nottingham. "The Problem of Hydrogen in Steel," by Dr. A. Lloyd. *Midland Branch:* Thursday, December 20, 6 p.m., James Watt Memorial Institute, Birmingham. Film Evening. *London Graduates' Section:* Wednesday, January 2, 6.30 p.m., Storey's-gate, St. James's Park, S.W.1. "The Development of the Mechanical Principles of Punched-Card Accounting Machines," by Mr. P. W. Murphy. *Institution:* Friday, January 4, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Considerations on Bogie Design, with Particular Reference to Electric Railways," by Mr. W. S. Graff-Baker. AUTOMOBILE DIVISION.—*Scottish Centre:* Monday, December 17, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. "Independent Rear Suspension," by Mr. Donald Bastow. *Western Centre:* Thursday, January 3, 6.45 p.m., The Royal Hotel, Bristol. Informal Discussion.

INSTITUTE OF FUEL.—*North-Eastern Section:* Monday, December 17, 6.30 p.m., King's College, Newcastle-upon-Tyne. "International Coal Classification" by Mr. D. Hicks. *Institute:* Tuesday, December 18, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Gasification by the Moving-Burden Technique," by Mr. J. W. R. Rayner. *Midland Section:* Tuesday, December 18, 6 p.m., James Watt Memorial Institute, Birmingham. "Developments in the Firing of Shell Boilers by Means of Chain-Grate Stokers," by Mr. C. H. G. Hayward.

INSTITUTION OF PRODUCTION ENGINEERS.—*Derby Section:* Monday, December 17, 7 p.m., Midland Hotel, Derby. "Recent Developments in the Economic Use of Materials," by Mr. G. F. P. Fox. *Manchester Section:* Monday, December 17, 7.15 p.m., College of Technology, Sackville-street, Manchester. "Management Ethics," by Mr. H. E. Roff. *Glasgow Section:* Thursday, December 20, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. "Legal Aspects in Industry," by Mr. A. E. Armour. *Reading Section:* Tuesday, January 1, 7.15 p.m., Great Western Hotel, Reading. "Industrial Design and the Engineer," by Mr. K. L. Brookfield. *Nottingham Section:* Wednesday, January 2, 7 p.m., Victoria Station Hotel, Nottingham. "The Importance of Costing to the Production Engineer," by Mr. L. W. Robson.

INSTITUTION OF WORKS MANAGERS.—*Glasgow Branch:* Monday, December 17, 7.15 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. Discussion on "Electronics." *Bristol Branch:* Wednesday, January 2, 7.15 p.m., The Grand Hotel, Bristol. "Management in a Research Organisation," by Mr. C. Bailey. *Tees-Side Branch:* Thursday, January 3, 7.30 p.m., The Vane Arms Hotel, Stockton. "The Profession of Management," by Mr. A. M. Hudson Davies.

JUNIOR INSTITUTION OF ENGINEERS.—*Sheffield Section:* Monday, December 17, 7.30 p.m., Co-operative Educational Centre, 201, Napier-street, Sheffield, 11. "Aluminium Alloys in General Engineering," by Mr. M. H. Levie. *Institution:* Friday, December 28, 6.30 p.m., 39, Victoria-street, S.W.1. "Hydro-Electric Power Developments," by Mr. J. Foster Petree.

INCORPORATED PLANT ENGINEERS.—*West and East Yorkshire Branch:* Monday, December 17, 7.30 p.m., The University, Leeds. "Museums: Their Work and Assistance to Industry," by Mr. C. M. Mitchell. *Glasgow Branch:* Tuesday, December 18, 7 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow. "Safety in the Use of Portable Electric Tools," by Mr. J. L. Wood.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS.—Monday, December 17, 7.30 p.m., University Building, St. George's-square, Sheffield. Annual Meeting. "A Rational Theory of the Hardening of Steel," by Mr. A. H. Marks.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS. —*Bournemouth Branch:* Monday, December 17, 8.15 p.m., The Grand Hotel, Bournemouth. "Electric-Resistance Heating," by Mr. T. F. Stanley. *London:* Tuesday, December 18, 6.30 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. "The Engineer in the Welfare State," by Mr. R. F. Mathieson. *Luton Branch:* Thursday, December 20, 8 p.m., The George Hotel, Luton. "Maintenance of Factory Equipment," by Mr. A. Carpenter.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, December 18, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. "Skidding and the Slippery Road," by Mr. C. G. Giles.

INSTITUTE OF INDUSTRIAL ADMINISTRATION.—*London Centre:* Tuesday, December 18, 7 p.m., 8, Hill-street, Berkeley-square, W.1. "Management in Practice." No. IV. "A Study in Improvements in Industrial Relations," by Mr. J. E. V. Tyzack.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*West Midlands Section:* Tuesday, December 18, 7 p.m., Wolverhampton and Staffordshire Technical College, Wolverhampton. "Design and Application of Industrial High-Frequency Heaters," by Mr. F. W. Budge.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Midlands Centre:* Tuesday, December 18, 7.30 p.m., The Crown Inn, Broad-street, Birmingham. "Piston, Rings and Cylinder Liners," by Mr. G. W. Yarwood. *North-West Centre:* Wednesday, December 19, 7 p.m., The Victoria Hotel, Wigan. "Garage Equipment and Service Tools," by Mr. R. M. Walker. *North-East Centre:* Thursday, December 20, 7.30 p.m., Hotel Metropole, King-street, Leeds. "Rear Axles," by Mr. R. H. Wilson.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, December 19, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "Warming of Arctic Air Masses Over the Eastern North Atlantic," by Mr. J. M. Craddock. (ii) "Modification of Continental Polar Air Over Hudson Bay," by Mr. F. E. Burbidge. (iii) "Observations with a Directional Rain Gauge," by Mr. R. E. Lacy.

ROYAL STATISTICAL SOCIETY.—Wednesday, December 19, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "The Interdependence of the British Economy," by Dr. T. Barna.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, December 19, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Railway Wind-Tunnel Work," by Mr. D. W. Peacock.

NEWCOMEN SOCIETY.—Wednesday, December 19, 5.30 p.m., Science Museum, South Kensington, S.W.7. "Canal Lifts and Inclines, with Particular Reference to Those in the British Isles," by Mr. David H. Tew.

ROYAL MICROSCOPICAL SOCIETY.—Wednesday, December 19, 5.30 p.m., Tavistock House South, Tavistock-square, W.C.1. "A Vector Theory of Phase-Contrast and Interference-Contrast," by Dr. R. Barer.

ILLUMINATING ENGINEERING SOCIETY.—*Tees-Side Group:* Wednesday, December 19, 6.30 p.m., Cleveland Scientific and Technical Institution, Corporation-road, Middlesbrough. "Street Lighting," by Mr. A. J. Ogle.

INSTITUTE OF WELDING.—*North London Branch:* Wednesday, December 19, 7.30 p.m., Manson House, 26, Portland-place, W.1. "The Application of Welding to the Electrical-Engineering Industry," by Mr. H. H. Reeve.

INSTITUTION OF ENGINEERING INSPECTION.—*West of Scotland Branch:* Wednesday, December 19, 7.30 p.m., 351, Sauchiehall-street, Glasgow. Films on "Productivity."

INSTITUTE OF BRITISH FOUNDRYMEN.—*North-East Scotland Section:* Wednesday, December 19, 7.30 p.m., Imperial Hotel, Arbroath. "Production of Castings for a Small Diesel Engine," by Mr. H. J. M. Conacher and Mr. R. Leeks.

INSTITUTION OF MINING AND METALLURGY.—Thursday, December 20, 5 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Mining Policy in French Overseas Territories," by Mr. F. Blondel.

ROYAL AERONAUTICAL SOCIETY.—Thursday, December 20, 6 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. "Control Surface Flutter," by Mr. E. G. Broadbent and Mr. W. T. Kirkby.

PERSONAL.

On medical advice, COLONEL THE HON. CYRIL SIDDELEY, C.B.E., T.D., is relinquishing the managership of the car side of Armstrong Siddeley Motors Ltd., Coventry, at the end of 1951, but remains a director.

SIR PERCY MILLS, K.B.E., vice-president of the Institution of Engineering Draughtsmen and Designers, Grand Buildings, Trafalgar-square, London, W.C.2, has been appointed adviser to the Ministry of Housing. Sir Percy has offered to undertake this task without remuneration.

MR. W. W. FRANKLIN, M.I.Mech.E., chief engineer of Davy and United Engineering Co., Ltd., Park Iron Works, Sheffield, 4, has been appointed a director of the company.

MR. J. ANDERSON, C.B.E., M.I.E.E., chief scientist at the Admiralty Signal and Radar Establishment, Haslemere; COLONEL A. V. KERRISON, director of Aeronautical and Engineering Research, Admiralty; and DR. E. C. S. MEGAW, director of Physical Research, Admiralty, have been promoted to the rank of Chief Scientific Officer in the R.N. Scientific Service.

MR. E. L. M. VAN GELDER has been elected President of the London Association of Engineers for 1952.

MERZ AND McLELLAN, 32, Victoria-street, London, S.W.1, are taking into partnership, as from January 1, 1952, MR. A. E. POWELL (who will be at their Newcastle office), MR. E. L. E. WHEATCROFT, and MR. H. J. BEARD (who will be at their Esher, Surrey, office), and MR. W. H. DIXON (who will be at their London office).

The Railway Executive announces that MR. C. A. GAMMON is to be assistant (wagon design), Carriage and Wagon Engineering Department, London headquarters; and that DR. H. I. ANDREWS, M.Sc., M.I.Mech.E., M.I.E.E., is to be general assistant, MR. W. J. WEBB, B.Sc. (Eng.), A.M.I.E.E., assistant for substations, and MR. E. CLAXTON, B.Sc. (Eng.), A.M.I.C.E., A.M.I.E.E., electrification engineer, in the electrical engineering new works and development organisation, London headquarters.

MR. C. B. V. NEILSON, M.A., A.F.R.Ae.S., M.I.E.E., A.M.I.Mech.E., chief designer (aircraft) to Electro-Hydraulics Ltd., Liverpool-road, Warrington, has joined the board as technical director.

The Minister of Fuel and Power has appointed SIR EWART SMITH, M.A., M.I.Mech.E., and CAPTAIN (E) W. GREGSON, R.N.R., to be members of his Scientific Advisory Council, set up in 1948. SIR HARRY R. RICARDO, F.R.S., and SIR HAROLD BROWN are no longer members of the Council.

MR. G. E. WHITTAKER has been elected President of the British Association of Machine Tool Merchants, West India House, 96-98, Leadenhall-street, London, E.C.3, for the coming year, in succession to MR. W. R. CLARKSON. MR. G. A. PARKER has been elected vice-president, and MR. E. J. F. BRADLEY re-elected honorary treasurer.

MR. HENRY D. CHALLEN, A.M.I.Mech.E., has been re-elected chairman of the British Power Press Manufacturers' Association, Standbrook House, Old Bond-street, London, W.1, for the 1951-52 session. MR. A. E. WHYMAN has been re-elected vice-chairman.

MR. JOHN BULMAN, general manager of the Marine Engine Works of R. and W. Hawthorn, Leslie and Co., Ltd., Newcastle-upon-Tyne, has been elected a director of the company.

MR. IRVIN HAYLOCK, F.C.A., has been appointed a director of Armstrong Shock Absorbers, Ltd., and of Armstrong's Patents Co., Ltd.

MR. C. A. ATCHLEY retires from the managing directorship of the Harland Engineering Co., Ltd., Alloa, as from January 1, 1952, but retains his seat on the board. MR. R. W. WEEKES, sales director, will fill the vacancy thus created, while MR. K. W. ATCHLEY will continue to be works director and chief of engineering. A wholly-owned subsidiary company, HARLAND DRIVES LTD., is being formed, of which MR. K. W. ATCHLEY will be chairman; MR. F. H. MADDOX, managing director; MR. R. C. MORTIMER, technical director, and MR. C. A. ATCHLEY, director.

MR. J. GRIFFITH HALL, a director and secretary of the Westinghouse Brake and Signal Co., Ltd., 82, York Way, King's Cross, London, N.1, has been appointed to the board of Westinghouse Garrard Ticket Machines Ltd.

MR. L. S. FAULKNER, who has been deputy district manager of the Norwich depot of the Dunlop Rubber Co., Ltd., for the last three years, has been appointed district manager in succession to the late MR. H. S. DOWNES.

MR. G. F. TEMPLE, formerly sales manager of British Polar Engines, Ltd., has now joined Modern Wheel Drive Ltd., Lindo Lodge, Stanley-avenue, Chesham, Buckinghamshire, and their associated company, Oil-Operated Gears and Transmissions Ltd., as sales manager.

THE BRUSH ELECTRICAL ENGINEERING CO., LTD., parent company of the BRUSH-ABOE GROUP, have acquired a 31 per cent. interest in the DIESEL EQUIPMENT CO., LTD., Vancouver, a selling organisation operating on the Pacific Coast of Canada.

THE PRODUCTION OF SMALL INTERNAL-COMBUSTION ENGINES.

PETTERS LIMITED, STAINES, MIDDLESEX.

(*For Description, see Page* 747.)

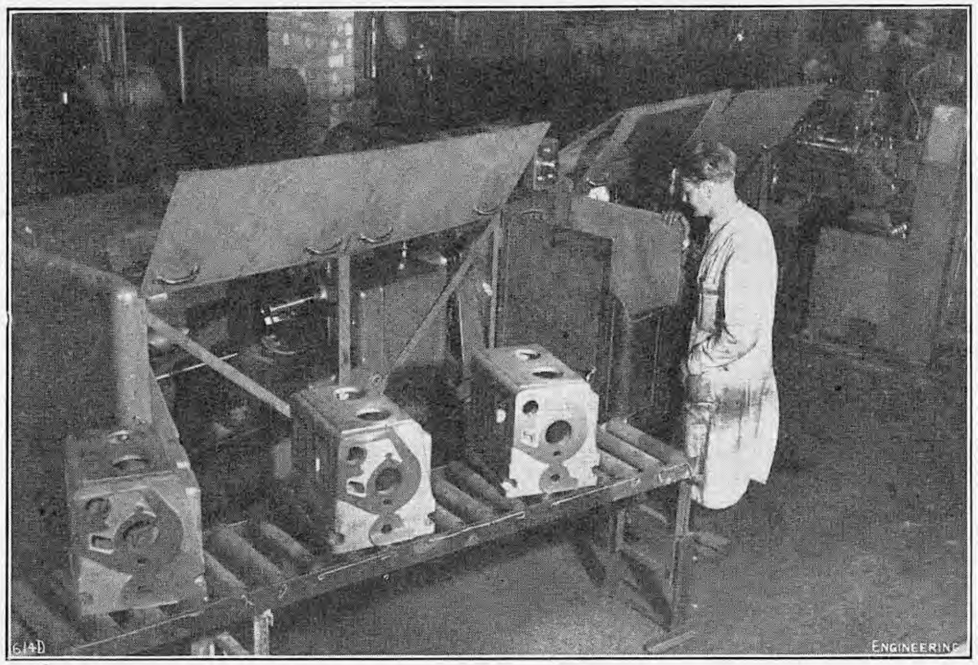


Fig. 4. Crankcase Drilling Machine.

Fig. 5. Delivery of Crankcases to Assembly Line.

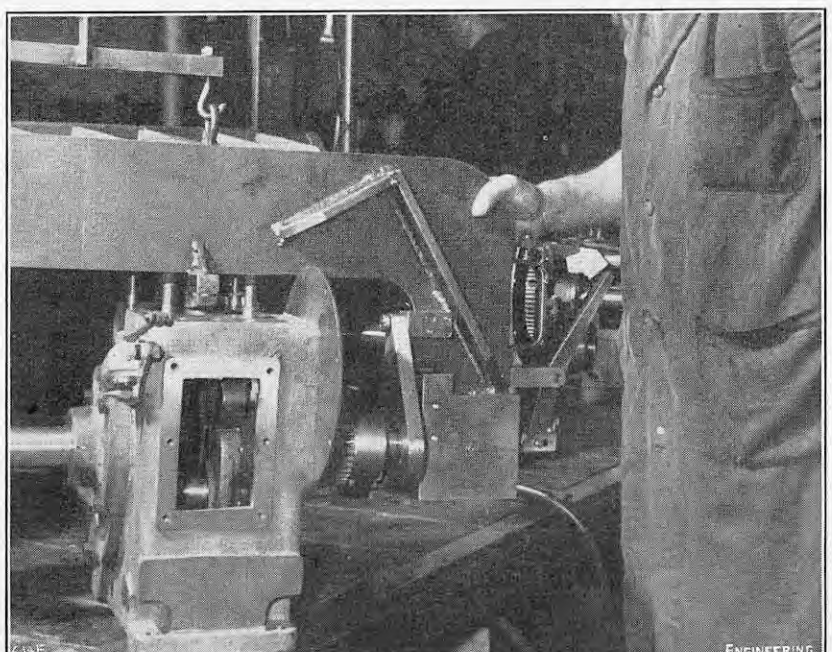


Fig. 6. Assembling Timing Gear on Crankshaft.

Fig. 7. Engine Test Shop.

ENGINEERING,

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INDEX TO VOL. 171.

The Index to Vol. 171 of ENGINEERING (January-June, 1951) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.

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ENGINEERING

FRIDAY, DECEMBER 14, 1951.

VOL. 172. No. 4481.

THE BRITISH GAS INDUSTRY.

DURING the year ended March 31, 1951, conditions in the British gas industry were such that emphasis had necessarily to be laid more upon the improvement of the service to consumers than on the promotion of new business. In fact, as is pointed out in the second report* of the Gas Council, the capacity of the producing plant in most parts of the country was insufficient to meet the additional demands upon it. Moreover, even if the plant had been adequate, there was still the fuel problem to be solved. On the distribution side, there was a similar tale. Delays in the delivery of materials, especially cast-iron pipes, restricted development, with the result that supplies to new housing estates, in particular, lagged behind requirements. Towards the end of the period under review the production of appliances was affected by the re-armament programme. Such publicity as was continued, therefore, was rightly directed towards encouraging economy in the use of gas and coke, and to advocating the employment of modern apparatus. This task was rendered more difficult by shortages of the necessary equipment.

Although this campaign towards greater economy must be conducted both in the domestic and industrial fields it is in the latter that it is more important, since in that sphere the applications of gas are constantly increasing in number and the demand is greater than it is possible at present to satisfy. To deal with this situation, an Industrial Gas Development Committee, composed of industrial gas officers nominated by the Area Boards, was therefore set up, so that each Area could be kept informed of developments throughout the country. Much of the work of this committee was concentrated on improvements in design and control of equipment so as to secure a saving in fuel; and it is satisfactory to be able to report that the results were frequently impressive. For instance, one large firm was able to increase its output by 44 per cent. with an increased fuel consumption of only 9 per cent., while in other cases reductions in consumption of as much as 20 per cent. were achieved.

These general statements regarding the position of one of the country's most important basic industries may be emphasised by referring in more detail to certain points of interest. During the year under review an aggregate of nearly 2,660 million therms of gas were produced, of which 2,334 million therms were made in the Board's own works. Of this output, 1,888 million therms was in the form of coal gas; water gas and other gases accounted for the remainder. In addition, some 318 million therms were obtained from coke ovens owned by the National Coal Board and other undertakings, while 7·2 million therms were bought from oil refineries. The resulting total of 2,660 million therms represents a satisfactory increase of over the figure for the corresponding period of last year, although direct comparison is not possible owing to the form in which the statistics are set out. Some idea of the progress that is being made can be gained, however, from the statement that 26,368,700 tons of coal were carbonised in the process of gas manufacture in 1950-51, compared with 25,263,700 tons in the previous twelve months, an increase of 4·4 per cent. The quantity of gas purchased from coke ovens also increased in about the same proportion. In addition, 556,700 tons of oil were gasified, principally to enrich the water gas that was made from coke.

Similar progress can be recorded in the coke and by-product branches of the industry. During the year nearly 12 million tons of coke were manufactured, of which 9·6 million tons were sold in this country. In addition, just over two million tons were consumed in the manufacture of water gas, in raising steam and for other purposes. Only the unsatisfactorily small amount of 630,500 tons was exported, owing to the imposition of restrictions on this trade. Rather over 2·7 million tons of breeze were also produced, of which 1·4 million tons were used in the works, and about the same aggregate amount was sold in the home and foreign markets combined. In considering inland sales it may be noted that the winter began early and ended late, though it was not of outstanding severity. The demand for solid fuel for space heating in the domestic, commercial and industrial fields was therefore continuous and rising, while the situation was also affected by the new armament programme. Stocks of coke at gas works therefore fell from over 1,100,000 tons at the middle of September, 1950, to 400,000 tons by the end of December; and delays in deliveries to domestic consumers increased in many districts to six or seven months. In addition to the embargo on exports, a system of priorities had consequently to be established, so that full deliveries could be maintained to essential users.

As regards by-products, nearly $1\frac{1}{2}$ million tons of crude tar were sold during the year. The demand for road tar was, however, restricted by the limitation of expenditure on roads. On the other hand, the amount of pitch used in the manufacture of briquettes and of pitch/creosote mixture for employment as fuel oil increased, as did also the demand for more specialised products, such as naphthalene and phenol. An interesting point is

* *Second Report and Statement of Accounts of the Gas Council for the Year Ended March* 31, 1951. London: H.M. Stationery Office. [Price 5*s.* net.]

that spent oxide, a material from which sulphuric acid can be manufactured, ceased to be a drug on the market and became a much sought after commodity, owing to a reduction in the quantity of pure sulphur which could be imported. On the other hand, there was some difficulty in disposing of such crude ammoniacal liquor as could not be converted into concentrated liquor or sulphate of ammonia, either by the Board or by the chemical industry. Finally, nearly 26 million gallons of crude benzole were recovered, about one half of which was refined by the Boards themselves.

Turning from manufacture to consumption, the sales of gas during the year under review amounted to 2,460 million therms, compared with 2,131 million therms during the eleven months ended March 31, 1950. If the latter figure is computed for a full year, the increase was of the order of 5 per cent. Of the total therms sold, 56·57 per cent. were bought by domestic consumers, 23·97 per cent. by industrial consumers, and 12·61 per cent. by commercial consumers. In addition, 2·17 per cent. of the output was consumed for public lighting and the remainder either by central or local government departments (categories which it is unusual to find shown separately), or for the Board's own purposes. Taking the industry as a whole, the year's working showed a net surplus of 1,492,784*l*. This gives an accumulative net surplus since vesting date of 1,941,232*l*., of which 1,035,000*l*. was placed to reserve. It may be noted that the surplus was obtained after 350,000*l*. had been contributed to the Central Guarantee Fund, which the Gas Council is required to establish, and after 6,874,661*l*. had also been provided for interest on British Gas Stock.

A close analysis of the report indicates both that the Gas Council and the Area Boards are actively striving to meet the increasing demands for gas in the face of difficulties, both with regard to coal supplies and plant shortages. As this state of affairs is likely to continue, it is not irrelevant to recall that the British Electricity Authority is encountering obstacles of much the same kind. The two industries are also similar in that both depend upon coal for their existence and both are large consumers of this national commodity. In fact, while the gas industry consumed some 26 million tons during 1950-51, the electricity supply industry used 34 million tons during the same period. The resulting aggregate of 60 million tons represents something like 27 per cent. of the national coal production, but while this production shows a distressing reluctance to rise, the consumptions of these two important industries exhibit an opposite tendency, in spite of all the economies that research and engineering skill have rendered possible. It is therefore essential that the search for further economies should continue with renewed vigour. It is desirable, however, that means whereby the two industries can co-operate should equally be sought. This is, of course, a thorny subject, since suggestions of such collaboration in the past have generally been based on restricting either gas or electricity to particular fields, thereby limiting the consumers' choice. Such limitation, even if it were possible to any extent that would be useful, is not, however, desirable. Co-operation must, therefore, be sought, and perhaps imposed, at the manufacturing rather than the utilisation end of the chain. The problem is undoubtedly difficult, and on the domestic side it is complicated by the fact that for many years it will still be necessary to burn large quantities of coal in open grates, although these may be of a more efficient type than most of those at present in use. Nevertheless, it is one which must be faced and solved, if the position of the country is not to deteriorate. It will certainly not be solved if the protagonists confine themselves to pointing out each others' weaknesses. They must come together and discover some solution in which the national interest is the primary consideration.

THE LOCOMOTIVE INDUSTRY.

THERE is always pleasure in finding that events have confounded prophets of woe. A report* on the locomotive industry, published eight days ago but evidently prepared well over a year ago, forecast a dwindling export market for the private builders, but events to date have refuted this idea. Within the past few weeks, the North British Locomotive Company have received a substantial share in orders worth 22,000,000*l*., which the South African Railways are placing this year—the largest in the railway's history—and builders generally, as recorded in our "Contracts" column from time to time, are experiencing no diminution of their post-war prosperity. If a slump is to come it seems to be a long way off, and in any case it could hardly be confined to the locomotive industry, or, indeed, to this country alone.

The gloomy forebodings of the report might have been less readily disproved if they had been published a year or two ago, when the available evidence pointed to such an appreciation of the prospects. Indeed, we ourselves were inclined to that view at the time, and said as much in our annual "Engineering Outlook" series of articles. We were confirmed in that view by the statement of at least one chairman of a large firm of locomotive builders, but, happily, the facts proved otherwise. *The Railway Gazette* last week quoted chapter and verse to show that "export orders have surpassed expectations." It may be that the prospects over a long term do not justify complacency, but surely no virile industry ever planned for the future except on the assumption that competitive and other difficulties will demand the utmost in resourcefulness and enterprise.

Though P.E.P. has published numerous reports since it was founded in 1931—*Locomotives* is the third of the engineering reports—its status may not be known widely outside this country. It is not an official organisation, in the sense of owing allegiance to the Government; it is an independent non-party research body, financed from private sources, whose objects are "to study questions on which public thought and discussion are needed, but on which the basis of factual knowledge is inadequate" and "to present the findings, both the facts themselves and the conclusions to which they seem to point, in an objective and readable way."

The locomotive report opens with a historical review and then turns to the statistics and facts of recent years, relating particularly to the output of the private builders and the railway workshops, orders for home and export, and the exports of the locomotive industries of other countries, in so far as they affect British builders. The principal conclusion of the report is that the private builders are not supported by an adequate home market to tide them over periods of depression, since it was the policy of the former railway companies—and is now the policy of British Railways—to build all or most of their locomotives in their own workshops. The conditions that obtained in the early 1930's are supposed to prove this thesis; no doubt, they do, but, unfortunately, the total outputs of locomotives from the workshops of the railways and the locomotive builders are not given for the critical years 1931, 1932 and 1933. Granted that, in 1933, the contractors only built one locomotive for the railway companies, who themselves built 219 in the same year, the relevant table in the report fails to give the number built for export. Furthermore, the total value of locomotives built by the contractors for the main-line railways in each of the years 1934, 1935 and 1936 actually exceeded each of the total values of exports. Locomotive builders certainly went through hard times in the early 1930's, but most of the world's industries suffered likewise; and we feel that it is hardly reasonable, in the same report, to blame British Railways and yet to state that, since the war, "the private builders have not been anxious for home orders, since their order books have been full with foreign business."

In addition to the effect of the manufacturing activities of the railways, the report dwells on two other factors, namely, the spread of industrialisation, particularly in India, and the rise of the Diesel locomotive. The two new locomotive works in India are not coming into production as fast as had been expected. Meanwhile, however, the Locomotive Manufacturers' Association of Great Britain are benefiting from the arrangement they made with the Indian Government whereby the British industry undertook to supervise the installation of plant and the initial stages of production, as well as to train key personnel in return for an assurance that India would buy from Britain such complete locomotives or components as could not be made in India. In the future, the development of economically backward areas may create new demands for steam locomotives, as the report states.

British builders, in co-operation with makers of oil engines and electrical equipment, have not been slow to enter the export market for Diesel locomotives, and though the home market is small it has not been reduced appreciably by the manufacturing activities of British Railways. In addition, the private builders have created a considerable business in Diesel industrial and mining locomotives. It is, in fact, in the development of locomotives other than steam types that the British builders are likely to find an expanding market to offset any diminution in steam-locomotive business. Undeveloped countries will continue, in many cases, to choose steam locomotives, because maintenance is simple, and if other countries, more industrialised, undertake their own steam-locomotive construction, British firms will be one step ahead in the development of newer forms of motive power. According to the best authorities, it is not too early to predict, with reasonable assurance, the advent of coal-burning gas-turbine locomotives, and in that field Britain is likely to be in the lead, with the United States. Such locomotives will be to coal-producing Britain what Diesel locomotives are to the oil-producing United States.

The P.E.P. report, in stating that "attempts are being made, particularly by American coal interests, to develop a form of turbine which will burn coal dust instead of oil," ignores the work that is being done, without much publicity, but nevertheless thoroughly, by firms and Government departments in this country. In his Thomas Hawksley Lecture to the Institution of Mechanical Engineers, Dr. Roxbee Cox has given a review of the work in this field which is being sponsored by the Ministry of Fuel and Power. Laboratory work has been done at the Fuel Research Station and the British Coal Utilisation Research Association; a Parsons gas turbine has been adapted experimentally to burn coal; a 2,000-kW gas turbine, designed from the outset as a coal-burning engine, has been in the hands of the English Electric Company, Limited; the Metropolitan-Vickers Electrical Company are building a 2,000-kW gas turbine with two-stage combustion; and the Ministry have ordered an open-cycle external-combustion coal-burning gas-turbine locomotive from C. A. Parsons and Company, and the North British Locomotive Company. Government-sponsored research and development of this kind has helped to put this country in the forefront of designers and builders of gas-turbine aircraft, and there is no doubt that the present work on locomotives will similarly be of great benefit to the locomotive industry in years to come.

* *Locomotives: A Report on the Organisation and Structure of the Industry, its Products and its Market Prospects at Home and Abroad.* P.E.P. (Political and Economic Planning), 16, Queen Anne's Gate, London, S.W.1. [Price 12*s*. 6*d*. net.]

NOTES.

THE INSTITUTION OF MECHANICAL ENGINEERS.

A PAPER on "The Measurement and Interpretation of Machinery Noise, with Special Reference to Oil Engines," was presented by Mr. C. H. Bradbury, M.I.Mech.E., at a meeting of the Institution of Mechanical Engineers, on Friday, December 7, with Mr. C. B. Dicksee in the chair. At the end of his paper, the author was able to make several recommendations to designers of oil engines on methods of reducing engine noise, and no doubt his approach to the problem could be applied with benefit to other machines. He first described methods of measuring noise, remarking that "the statement that the average sound level is x decibels is now regarded as having little meaning." With the equal sound-level contour method, points of equal sound level on a chosen plane through, say, an oil engine, were joined by "contour" lines, thus revealing the noisiest zones. To analyse further the causes of noise, a frequency spectrum, or narrow-band analysis, was prepared; predominant frequencies were clearly shown and, with a full knowledge of the machine characteristics, sources of noise could often be traced. In the octave-analysis method, a frequency spectrum was obtained with an octave filter, thus giving the general distribution of noise according to frequencies. If, as a result of examination by a frequency spectrum, an "unpitched" noise was discovered, i.e., a noise which bears no special relationship to the speed of the machine, an analyser instrument was set for the frequency of the unpitched noise and it was traversed around the machine to give an indication of the source. A full appreciation of the recorded results, Mr. Bradbury said, was not easy if the object was to reduce noise and to understand what constituted "objectionable noise." Octave spectra showed that objectionable noise was associated with frequencies over 500 cycles per second; a level of, say, 90 to 100 decibels at the low-frequency end might mean relatively little noise. If the sound level within the range of frequency of normal speech was greater than that of a loud voice, conversation was difficult. This criterion of "objectionable noise," together with "the avoidance of nervous strain when working manually or mentally in the immediate neighbourhood of the machine," was suggested by the author. To make noise less annoying, he said, consideration must be given mainly to the reduction of sound levels in the range 200 to 10,000 cycles per second; in an oil engine such sounds were not due to the basic disturbing frequencies of pistons, firing strokes, etc., but to unpitched or response frequencies, the excitation of which was due fundamentally to design. Since such high-frequency sounds were caused by undamped vibration which was shock-excited, the primary object must be to reduce shock loading. Mr. Bradbury then turned to the several principal sources of noise in an oil engine and recommended certain points to designers. In particular, he mentioned piston "slap" (reduced by low-expansion piston material and by close control of the shape of the piston clearance from skirt to top ring); the firing impulse (the ratio of maximum to compression pressure was the controlling factor); valve gear (the fuel pump must not be operated from the valve camshaft); and fuel-injection equipment. There was, he thought, good reason to believe that the latter was the major source of oil-engine noise; high-frequency noise due to the fuel pump depended on its mounting, and it was most important to provide an adequate support, ribbed so as to eliminate any possibility of a diaphragm effect.

THE BRITISH CONTRIBUTION TO TELEVISION.

As already announced, a convention on "The British Contribution to Television" will be held at the Institution of Electrical Engineers from Monday, April 28, to Saturday, May 3, 1952. The convention will be divided into a number of sessions, preceded by the opening ceremony, which will be followed by an introductory survey paper by Sir Noel Ashbridge. After that, a historical session will be devoted to a paper showing the evolution of television from the end of the Nineteenth Century to the opening of the regular British Broadcasting Corporation's high-definition service in November, 1936. Programme organisation, covering cameras, camera channels, studio lighting and film scanners, will be dealt with in a third session, and a fourth will comprise point-to-point transmission, permanent and temporary cable and radio links and television-transmission measuring equipment. At other sessions, broadcasting stations, propagation, receiving equipment, non-broadcasting applications (such as medical applications and film aids), and finally, the fundamental aspects of colour television, test equipment and subjective aspects of viewing and contrast will be dealt with. It is expected that between 60 and 80 papers, many of which have already been received, will be presented. During the technical sessions there will be demonstrations, including one of large-screen projection television and, it is hoped, of an early Baird 30-line equipment. Visits will be paid to the British Broadcasting Corporation's television studios and transmitters, to the Post Office research station, the terminal equipment of the London-Birmingham coaxial cable link and to certain commercial organisations. Those desiring to attend the convention are asked to apply for details to the Secretary as soon as possible. Advance copies of the papers will be available during April, 1952, and will generally be supplied in sets, each of which will comprise those allocated to a particular session. After the convention the papers and the discussions on them and the addresses will be published in four issues of Part IIIA of the *Proceedings*. Applications for these issues should be made at the same time as for the proofs.

STEEL ECONOMY IN REINFORCED CONCRETE.

Since there is at present an urgent need for economy in the use of steel, the Council of the Reinforced Concrete Association have been considering a suggestion that the working stress of mild-steel reinforcement complying with B.S. 785, "Rolled Steel Bars for Concrete Reinforcement," might be safely increased from its present value of 18,000 lb. per square inch, which would make it possible to reduce the quantity of steel used in reinforced-concrete structures. Recent tests have shown that the yield stress in mild-steel bars of small diameters is generally at least 36,000 lb. per square inch, and the Council have therefore come to the conclusion that, for bars of $\frac{7}{8}$ in. diameter or less, a working stress of 20,000 lb. per square inch could be safely adopted except in the design of liquid-retaining structures, etc. This stress is higher than that recommended in the British Standard Code of Practice (CP 114-1948) for the structural use of normal reinforced concrete in buildings, but the Association do not consider that the code, which is not mandatory and can be modified at the discretion of the engineer, should be altered to meet temporary emergencies. The building by-laws of the London County Council, however, which limit the working stress of steel reinforcement to 18,000 lb. per square inch, are mandatory, but their requirements may be modified by "waiver" under Section 9 of the London Building Act (Amendment) Act 1935. The Council of the Reinforced Concrete Association have, therefore, sent to the London County Council a copy of a memorandum recommending that applications for such a waiver should be sympathetically considered. The Council are considering whether it might be possible to put forward a similar recommendation relating to mild-steel bars of diameter greater than $\frac{7}{8}$ in.

CASUALTIES TO SHIPPING IN 1950.

Statistics of merchant ships of 100 tons gross and above which have become total losses or have been condemned or broken up during the calendar year 1950 have been published by Lloyd's Register of Shipping, 71, Fenchurch-street, London, E.C.3. These show that 225 ships, making together 263,991 tons, were lost at sea or were condemned, consequent upon casualty or stress of weather, and that, of these ships, 28, totalling 63,103 tons, were owned in Great Britain and Northern Ireland. Vessels otherwise broken up or condemned during 1950 numbered 410, aggregating 937,206 tons, and, of these, 116 ships, comprising 293,940 tons, flew the British flag. Of the vessels which became total wrecks during the year under review, 18, making together 42,057 tons, were owned in the United Kingdom, and among them were the 7,404-ton motorship Clam, wrecked on rocks off Iceland on February 28; the 7,236-ton steamer Marietta Dal, wrecked on Smith Rock, off Cape Moreton, Queensland, Australia, on May 15; the 7,090-ton steamer Empire Gladstone, which struck Haystack Rock, 8 miles north of Twofold Bay, New South Wales, on September 5; the 8,371-ton twin-screw steamer Bisco 9, which became stranded on a reef $3\frac{1}{2}$ miles north of Davaar Island, Mull of Cantyre, on September 17; and the 4,251-ton steamer Skeldergate, lost in the Bay of Bengal during heavy weather on November 17. Two British ships were lost by fire; they were the 6,318-ton S.S. Benledi in the Mediterranean on February 24 and the 7,319-ton S.S. Indian Enterprise which sank in the Red Sea after an explosion on June 19. Two steamers owned in the United Kingdom were lost as the result of striking mines; they were the 3,494-ton Anhui, which became a casualty on June 16, while on a voyage from Hongkong to Swatow, China, and the 410-ton Fenstone, sunk by a mine in the North Sea on July 14. The British vessels broken up for various reasons, during 1950, included the S.S. Aquitania, of 44,786 tons, built in 1914; the S.S. Pakeha, of 8,115 tons, built in 1910; the S.S. Nestor, of 14,629 tons, built in 1913; the M.S. Malayan Prince, of 8,593 tons, built in 1926; the S.S. Orbita, of 16,538 tons, built in 1915; and the S.S. Raranga, of 10,043 tons, built in 1916. Of foreign-owned ships, among the largest to be broken up during 1950 were the French S.S. Désirade, of 9,645 tons, built in 1921, and the Panamanian oil-tank steamer Phoebus, of 8,863 tons, built in 1923.

THE ROYAL AGRICULTURAL SOCIETY.

In presenting the report of the Council to the annual general meeting of the Royal Agricultural Society, Lt.-Col. H. J. Cator, M.C., the retiring President, mentioned that present expectations are that there will be a profit from this year's Royal Show, which was held at Cambridge in July. He also referred to the recent increase in the Society's membership subscription rate, mentioning that it was with the greatest reluctance that this decision had been made; the cost to the Society of each member's privileges, however, was exceeding the old rate and, as a consequence, the Society's accounts for 1950 had shown a deficit. The report is, of course, of most use to farmers, but there are a number of items of interest to agricultural engineers. In referring to the potato-harvester competition, first announced in 1949, it is stated that the number of entrants is surprisingly high, a total of 29 complete harvesters having been put forward before the list closed at the end of August, 1951. A particularly pleasing aspect is the number of entries of machines for separating stones from potatoes. The trials will take place in 1952 in three types of land, namely, stony, heavy and light fen soils, and a national demonstration of all entries is projected for the second week in October on a site near Newport, Shropshire.

OBITUARY.

MR. A. VINES.

WE regret to record the death of Mr. A. Vines, which occurred at Richmond, Surrey, on Saturday, December 1. He was in his 85th year and had long been known for the part he had played in the development of electrical measuring instruments as a founder member of the firm of Evershed and Vignoles, Limited.

Adolph Vines was born in London and received his education privately and at Emmanuel College, Cambridge, where he graduated as Master of Arts. He joined the firm of Evershed and Vignoles as works manager when it was formed in 1895, and was joint managing director from 1909 to 1940. In the latter year he retired from active management, but was elected chairman, a position he was holding at the time of his death. During that period the firm made a great contribution to the art and science of electrical measurement, a statement which may be illustrated by saying that the number of employees grew from eight at the time of its formation to over 1,300 at the time of Mr. Vines' death.

Mr. Vines was elected an associate of the Institution of Electrical Engineers in 1891 and transferred to the class of member in 1904. He was a past-president and trustee of the Engineering and Allied Employers London and District Association and had also been vice-president of the British Engineers' Association and vice-chairman of the British Scientific Instrument Research Association. Until a short time before his death he was a member of the Management Board and Conference Committee of the Engineering and Allied Employers' National Federation.

MR. B. M. JENKIN.

ELECTRICAL engineers of the older generation will learn with regret of the death of Mr. B. M. Jenkin, which occurred at Bristol on Monday, December 3, at the advanced age of 84. In his early days he had played a large part in various branches of electrical development, but had for many years devoted his attention to farming on scientific lines.

Bernard Maxwell Jenkin was born in Edinburgh on August 5, 1867. He was the youngest son of Professor Fleeming Jenkin, who was the first holder of the chair of engineering in Edinburgh University and who played a leading part in devising means for measuring electrical quantities and in determining the British Association system of units. The son was educated at the Edinburgh Academy and University; and also attended classes at the School of Engineering, Hanover-square, London, where he took the first place in his year. In 1886, he entered the works of Messrs. Mather and Platt, Limited, of Salford, as an apprentice, but in 1888 went to the Crewe works of the London and North Western Railway, where he spent two years as a pupil of F. W. Webb. Subsequently, he travelled in the United States for some months and then returned for a time to Edinburgh University.

In 1891 he was engaged as an assistant by Dr. A. B. W. (afterwards Sir Alexander) Kennedy, who was then practising as a consulting engineer, and, after becoming chief assistant in 1876, was taken into partnership in 1879. During his association with Sir Alexander, the firm carried out a number of electricity supply and electric traction schemes in this country, including those at Manchester, Edinburgh, Glasgow, Croydon, Carlisle and York, and on the Waterloo and City and Hammersmith and City Railways, as well as the tramways at Rotherham, Darlington and Kilmarnock. His part in these developments was undoubtedly influenced by his early association in his father's home with such pioneers as Kelvin, Clark Maxwell and Ewing; and his contacts with Robert Louis Stevenson and other great men of the Victorian age enabled him to bring to engineering a scholarly mind and progressive outlook.

In 1913, Jenkin retired from consulting engineering for reasons of ill-health, but in its place successfully took up farming on scientific lines until advancing years prevented him from devoting to it the personal attention to detail that characterised all his work. He gave some account of his work in this field in the course of a discussion on a paper by R. Borlase Matthews, which was read before the Institution of Electrical Engineers in 1922. He himself had read papers before the Institution of Civil Engineers—one in 1899 on the electrical equipment of the Waterloo and City Railway for which he was awarded the Telford Premium; and another in 1902 (in collaboration with W. M. Mordey) on electric traction on railways, which gained him the George Stephenson Medal. It may be recorded that the discussion on the latter paper extended over five meetings.

Jenkin was elected an associate member of the Institution of Civil Engineers in 1892 and was transferred to the class of member ten years later. He became a student of the Institution of Electrical Engineers in 1886 and a member in 1898. He was also for many years a member of the Institution of Mechanical Engineers.

LETTERS TO THE EDITOR.

THE SAMPLING OF SMALL COAL.

TO THE EDITOR OF ENGINEERING.

SIR,—In his letter on page 692 of your issue of November 30, Mr. R. C. Tomlinson states, in effect, that the best method of finding the variance of a particular coal is to measure it. I can only say I agree, so long as it is practicable to do so. He advocates the use of a well-known technique for estimating the variance from a number of pairs of observations. Again, I agree. He further advocates the use of quality-control charts for keeping a running check on the properties of the substance; the advantages of this procedure are too well-known to need my endorsement. It is inherent in the method, however, that the consumer does not obtain the desired information until a number of consignments, representing, perhaps, several thousands of tons, have been received and burnt. Mr. Tomlinson mentions that the method has been adapted to the sampling of an isolated consignment (by which I presume he means a coal of which we have no prior knowledge of the sampling characteristics), but it is small consolation to a consumer who has conducted an expensive boiler trial to obtain information afterwards showing that the sampling carried out during the trial was inadequate.

Mr. Tomlinson's method obviously has valuable uses, for example at a mine where the number of coals to be dealt with is small and the same coals are sampled day after day; but consumers who receive a relatively large number of different coals, and who are subject to frequent changes of supplies, need a method of estimating the sampling properties of a coal from other known or reputed properties such as source, size, treatment, average ash content, etc. My article deals with the principles which must be observed in establishing such a method of estimating. It draws attention to, and takes account of, the facts mentioned by Mr. Tomlinson that "Not only are coals inherently different in their 'patchiness,' but the method of handling and preparation, as well as the mixing of different seams, are all factors which affect the sampling accuracy." I do not, however, share the view expressed by the phrase "to an unpredictable extent."

It is stated that "In general it would appear that no solution can be obtained by theoretical means without a large number of assumptions." I should like to point out that the article deals only with fundamentals and that, except for the purpose of illustration, no particular laws are assumed for the variations of the quantities involved. It is not suggested that the same laws will be found suitable for all classes of coal. It is not even assumed that r_{qm} (equation 6) is positive, although, apart from the fact that experimental evidence exists, commonsense suggests that it could hardly be otherwise when q is small. The term $2 \Sigma m (n-q) C_{qm}$ obviously has the same sign as r_{qm}.

I have no objection to raise if Mr. Tomlinson wishes to use some alternative name for the quantity denoted by r_{qm}, or even to leave it without a name. I cannot understand his statement that the variance, S^2, of single increments (as expressed by equation 9) is zero. If this were the case we should not have any sampling problems.

Yours faithfully,
E. T. G. EMERY.

21, Brockenhurst-way,
Norbury,
London, S.W.16.
December 5, 1951.

SOLVING BEAM PROBLEMS BY RELAXATION METHODS.

TO THE EDITOR OF ENGINEERING.

SIR,—The article by Mr. R. C. Coates on page 456 of your issue of October 12, 1951, is most interesting, particularly as there is such a dearth of understandable literature on the subject of relaxation. Some of the arguments, however, seem to be a little difficult to follow and I trust, therefore, that I may be pardoned for taking the liberty of giving a few supplementary remarks, with special reference to the simply-supported beam problem of Fig. 2.

Considering the relaxation at station 2: the beam is assumed to be initially constrained so that it cannot deflect at all. Then, at station 2, for instance, it follows from equation (3) that the initial constraint $R_2 = -\frac{M_2 d^2}{E I}$.

Now let station 2 alone be relaxed by a deflection of δy_2. Then, if R_2' is the constraint after this operation,

$$\begin{aligned} R_2' &= y_1 - 2 y_2 + y_3 - \frac{M_2 d^2}{E I} \\ &= 0 - 2 \delta y_2 + 0 - \frac{M_2 d^2}{E I} \\ &= -2 \delta y_2 + R_2. \end{aligned}$$

For R_2' to be zero, $R_2 = 2 \delta y_2$, or $\delta y_2 = \frac{R_2}{2}$.

Thus, an increase of $\frac{R_2}{2}$ in the deflection at station (2) tends to reduce the constraint there to zero or, conversely—and this is the important point—if the constraint at station 2, initially of value R_2, be made zero, the corresponding deflection is $\frac{R_2}{2}$.

As regards the effect on constraints at (1) and (3), there will be an increase of $\frac{R_2}{2}$ in the residuals at stations 1 and 3. In other words, there is carry-over of $\frac{R_2}{2}$ to stations 1 and 3, thus:—

Station 1.	Station 3.
$R_1 = -\frac{M_1 d^2}{E I}$ when $y_1 = y_2 = 0$	$R_3 = -\frac{M_3 d^2}{E I}$ when $y_2 = y_3 = y_4 = 0$
$R_1' = -2y_1 + y_2 - \frac{M_1 d^2}{E I}$	$R_3' = y_2 - 2y_3 + y_4 - \frac{M_3 d^2}{E I}$
$= 0 + \frac{R_2}{2} + R_1$	$= \frac{R_2}{2} - 0 + 0 + R_3$
$= \left(R_1 + \frac{R_2}{2}\right)$	$= \left(R_3 + \frac{R_2}{2}\right)$

Block Relaxation.—By exactly similar reasoning to that used above, it can be shown that if, say, stations 2 and 3 are relaxed simultaneously, by an amount R, the corresponding deflection at stations 2 and 3 is R and the carry-over to stations 1 and 4 is R.

In the relaxation table below, figures in ordinary type are residuals; bold figures to the left of the vertical lines are deflections. Carry-over is indicated by arrows.

		(1)	(2)	(3)	(4)	(5)
Initial residuals ..		67	133	100	67	33
Relax(2) ..		66←	−133→	66		
		133 **66**	0	166	67	33
Relax(3) ..			83←	−166→	83	
		133	83 **83**	0	150	33
Relax (1) ..		−133→	67			
	67	0	150	0	150	33
Relax (2), (3), (4) ..		150←	−150		−150→	150
		150 **150**	0 **150**	0 **150**	0	183
Relax (1), (2), (3), (4), (5) ..						
			Etc.			

Yours faithfully,
WILLIAM MORSE,
Chief Technician (Aircraft Section).
Alan Muntz and Company, Limited,
Heston, Middlesex.
November 23, 1951.

LIGHTING OF LOCOMOTIVE INSPECTION PITS.—The General Electric Company, Limited, Kingsway, London, W.C.2, have designed a special fluorescent lighting fitting for building in to the walls of locomotive inspection pits. Each fitting, containing a 5-ft. 80-W lamp, has an inclined armour-plate protecting glass and a polished aluminium reflector for directing the light upwards between the frames of the locomotive. Several of the fittings have recently been installed in pits at the Beckton gasworks of the North Thames Gas Board.

EXHIBITS AT THE SMITHFIELD SHOW, EARL'S COURT.

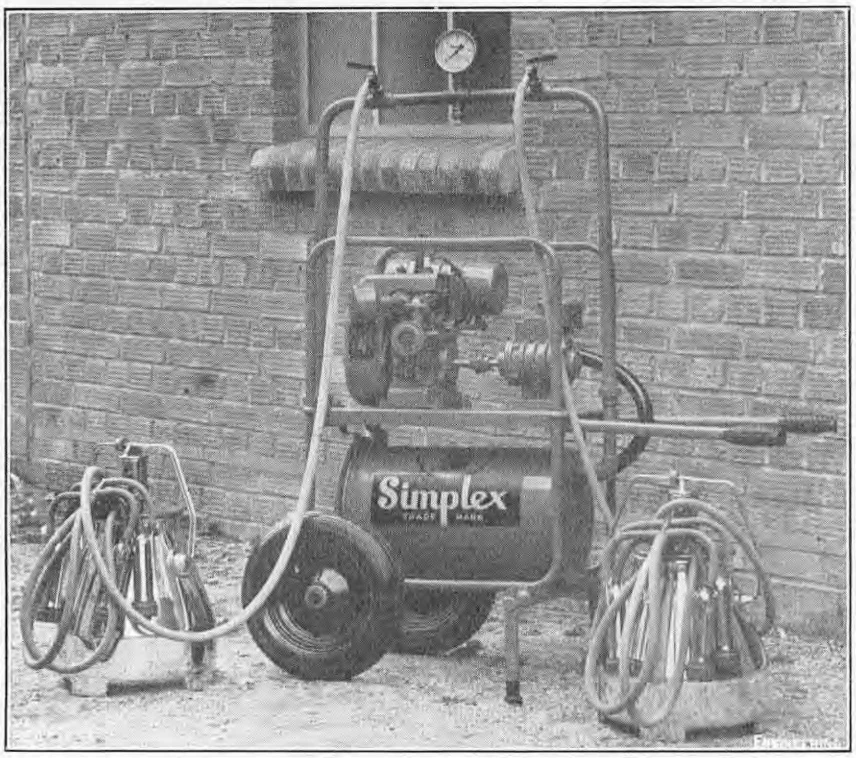


FIG. 7. "UNIVERSAL" PORTABLE MILKING MACHINE; SIMPLEX DAIRY EQUIPMENT COMPANY, LIMITED.

FIG. 8. "DOWNHAM-SIMPLEX" SPRAYING TUNNEL; SIMPLEX DAIRY EQUIPMENT COMPANY, LIMITED.

THE SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION.

(*Concluded from page* 714.)

IN recent years, much greater attention has been paid to milk production, and the dairy farmer has been called on for ever-increasing yields from his herds. As a consequence, he has had to take advantage of every possible method of overcoming shortage of labour, and there is little doubt that, were it not for the milking machine, present-day demands for milk and its allied products could not have been met. Although the Dairy Show is the main *venue* for showing such machines, several examples were being exhibited at Earl's Court; the Simplex Dairy Equipment Company, Limited, Cintra House, Hills-road, Cambridge, for instance, were showing a wide range of milking equipments, including the portable machine illustrated in Fig. 7, on this page. This machine should prove most useful to owners of small herds as it is completely portable and can be taken, therefore, to herds in the fields and from one cow house to another. The unit is mounted on a tubular frame and comprises a vacuum tank and exhauster, together with the necessary piping, cocks, etc., for connecting it to two Simplex milking units. The exhauster is driven either by a small Villiers petrol engine, as shown in the illustration, or by an electric motor, the general design of the exhauster following that used in Simplex fixed milking installations. Similarly, the milking units are of the firm's standard type, each incorporating a pulsator in the cover.

The Simplex Dairy Equipment Company, Limited, were also showing the animal-spraying tunnel illustrated in Fig. 8, on this page. Known as the Downham-Simplex spraying tunnel, it has been designed to replace permanent dipping baths, the main advantage being that it can be used anywhere, the only ancillary equipment required being a pump and a tank for the disinfectant. Other advantages claimed for it are economy in use of disinfectant and reduced danger of injury to the animals being treated. It consists of a tubular-steel framework over which is stretched a canvas cover; nine adjustable nozzles from which the fluid is sprayed are arranged in the framework in positions calculated to give the best coverage of the fleece. The tunnel is made in three sections, each 5 ft. long, 3 ft. wide and 4 ft. 10 in. high, the joints being designed so that the complete unit can be dismantled easily for transport to another site. It is claimed that 50 sheep a minute can be sprayed by one man and a trained sheepdog, and that only 10 per cent. of insecticide is used as compared with dipping. Only the disinfectant drained from the tunnel walls is used again, any dripping from the animals being allowed to run to waste so as to avoid any possibility of contamination. The unit described is suitable for sheep only, a larger structure being required for cattle and horses. This has a height of 7 ft. 2 in. and a width of 5 ft., while the number of spraying nozzles is increased from nine to sixteen.

As in past years, the Smithfield Show was international in character, several continental firms being represented either directly or by their British agents. Mr. T. R. Walker, of Bilbrough, Yorkshire, for example, was showing a wide range of Kaybee grain and seed cleaning and handling machinery manufactured at Malmoe, Sweden. The equipment on view included the Kaybee type "K" hammer mill which was being shown for the first time. This unit, which is illustrated in Figs. 9 and 10, on page 758, is essentially a static machine, requiring about 30 h.p. to drive it. The general design will be apparent from a study of Fig. 10; this shows the unit with the side cover swung back, and it will be noted that the rotor is in the form of a fan with "hammers" fitted to alternate blades. A shaker-feeder is installed on the top of the machine and this is arranged to discharge into the main feed chute in the front cover, the chute incorporating a magnet and a stone trap for the removal of extraneous material. Screens having different meshes are available, each screen being in the form of a complete ring and the design such that it can easily be removed and replaced. In conformity with most machines of this class, the "hammers" are reversible and, when worn, can be replaced with the minimum of trouble. The draught set up by the rotor and associated hammers is considerable and is sufficient for a discharge height of from 20 ft. to 25 ft.

The use of rotary hoes for the general cultivation of land is gaining steadily in popularity; Rotary Hoes, Limited, East Horndon, Essex, one of the leading makers of this type of implement, have, from time to time, introduced machines suitable for use behind most of the leading makes of tractor. At this year's show, their exhibits included a rotary cultivator designed for use with large crawler-type tractors and capable of being used for land-clearance purposes. The unit, which is known as the Howard Rotavator heavy-duty attachment, is illustrated in Fig. 11, on Plate XLVIII, behind an International tractor; it can also be used with other tractors. In general, the design of the implement follows the maker's standard practice, consisting of a heavy rotor arranged horizontally behind the tractor. The rotor comprises a series of true hoe blades designed to have a positive cutting and dividing effect and arranged to form a number of helices about the rotor hub. It is driven through a two-speed gearbox from the tractor power take-off, rotation being in the direction of travel and the gearing designed to give several turns of the rotor for each foot of forward travel of the tractor. The rotor is controlled by means of a clutch in the tractor power take-off but further spring-loaded clutches are incorporated in the drive to act as a safety release should the blades strike an obstruction. The complete unit is raised and lowered by means of a hydraulic-lift, but there is also a hand-operated winch which secures the rotor when travelling to or from work and can also be used to control the depth of working, a function normally carried out by skids.

Rotary Hoes, Limited, were also showing the latest edition of their Gem machine, a self-contained rotary-cultivator suitable for market-garden work, and an air compressor for use in conjunction with their Bantam machine. The former machine, which has been designated the Gem series IV Howard Rotavator, is illustrated in Fig. 14, on Plate XLVIII, from which it will be seen that it is controlled by hand. The general design follows earlier machines of this class, but it is fitted with a two-cylinder engine of the maker's own design and manufacture and capable of developing over 9 brake horse-power; as a consequence, it can be fitted with a 30-in. rotor in place of the standard 24-in. rotor. The engine is a four-stroke air-cooled two-cylinder unit having a bore and stroke of 3 in. and $3\frac{1}{2}$ in., respectively, and governed at 2,000 r.p.m., at which speed it develops $9 \cdot 1$ h.p.

The compressor attachment for the Bantam machine, a smaller version of the Howard Rotavator, is illustrated in Fig. 15, on Plate XLVIII, where it is shown installed in the working position. The compressor, which, together with its ancillary equipment, is manufactured by the Hymatic Engineering Company, Limited, Redditch, Worcestershire, is a single-cylinder single-stage air-cooled unit operating at 2,000 r.p.m. and having a displacement of 7½ cub. ft. of air per minute. The working pressure is 100 lb. per square inch and the unit is supplied complete with an air receiver having a capacity of 355 cub. in. and tested to twice the working pressure. The complete unit is easily fitted to the cultivator, being mounted on a special sub-frame which, in turn, is supported by a small castor wheel. It is driven from the rotor power take-off and the design is such that it can be installed in position in a few minutes. Auxiliary equipment suitable for use with the Hymatic compressor includes a hedge-cutter, a spray gun, a pressure-feed container and an air hammer.

As already mentioned, several new tractors were being shown to the public for the first time at Earl's Court. These included the Ota Monarch, a light four-wheel tractor manufactured by Oak Tree Appliances, Limited, Coventry, and marketed by Slough Estates (London), Limited, 16, Berkeley-street, London, W.1. This machine, which is illustrated in Fig. 12, on Plate XLVIII, has been developed to meet the demand of the small farmer who needs a light tractor capable of performing on a reduced scale all the functions of the larger machines. The design of the Monarch is based, largely, on that of the three-wheel tractor introduced by Oak Tree Appliances some two years ago. It is powered by a Ford-Industrial four-cylinder engine capable of operating on either petrol or kerosene and developing a maximum output of 17 h.p. The transmission assembly comprises a Ford clutch and three-speed gearbox, which form a single unit with the engine, and an auxiliary two-speed gearbox; the total number of speeds available, therefore, is six, the ratios of which give road speeds ranging from ¾ mile per hour to 15 miles per hour. Final drive to the rear wheels is through a worm and worm-wheel assembly, which incorporates a standard bevel-type differential; a special high-tensile alloy bronze is used for the worm wheel, and the worm shaft and worm profile is machined from a nickel-chrome case-hardening steel to specification EN36. Girling internal-expanding brakes are fitted to the rear wheels and these are arranged so that they can be operated either together or separately with suitable provision for parking. The wheel track is adjustable between the limits of 3 ft. 6 in. and 5 ft. and the minimum turning radius is approximately 8 ft., car-type steering being employed. The wheelbase is 5 ft. 2 in., the ground clearance at the lowest point 16 in., and the weight approximately 13 cwt. Auxiliary equipment available with the tractor includes a hydraulic pump and implement-lift assembly, a power take-off, a four-speed belt-pulley drive and a B.E.C. radiant-heat unit for converting the engine to run on kerosene.

In our issue for last week, reference was made to the developments made recently in the design of mechanical-handling equipment for use on farms, and it was suggested that this was due to the growing popularity of hay and straw baling machines and the ensuing difficulty in handling the bales, particularly when stacking. These difficulties can be overcome largely, however, by employing portable elevators, and a good example of such a machine was shown by Messrs. A. B. Blanch and Company, Limited, Crudwell, Wiltshire. This unit, which is known as the Blanch 18-ft. elevator, is illustrated in Fig. 13, on Plate XLVIII, where it is shown loading bales into a Dutch barn, a purpose for which it is eminently suitable. The bed is 21 ft. 9 in. long and the height of delivery can be adjusted from a minimum of 9 ft. to a maximum of 18 ft. The conveyor, which is of the endless-slatted type, is driven by a Petter 2-h.p. petrol engine situated in the chassis, the transmission comprising a belt drive to a countershaft and then chains to the conveyor-driving sprockets. The height of delivery is varied by altering the position of the supporting strut, which is designed to pivot about its lower end and slide in guides formed in the conveyor bed at its top end, the position being altered by means of a small hand winch and associated wire rope. As will be seen from the illustration, the unit is portable, being fitted with pneumatic-tyred wheels and provided with a towing frame. The capacity is 5 cwt. and optional equipment available with the machine renders it equally suitable for handling root crops, manure, loose hay, straw, etc.

Mention has been made from time to time in ENGINEERING of the remarkable versatility of small hand-controlled cultivators. Several machines of this class were being shown at Smithfield, a good example being furnished by the Clifford rotary cultivator, which is manufactured by Clifford Aero and Auto, Limited, Cranmore Boulevard, Shirley, Birmingham, and is capable of performing tasks ranging from cultivation to ploughing and lifting potatoes. It is illustrated in Fig. 16, on Plate XLVIII, where it is shown fitted with a 2 ft. 6 in. cutter bar, a handy attachment for use in orchards and other confined spaces not normally accessible to tractor-operated cutter bars. The drive mechanism incorporates a safety clutch to prevent the blade from being damaged should it strike a hidden obstacle and the complete mechanism can be swung up to clear gateways, etc., without disturbing the drive. Details of the actual Clifford cultivator have been given previously in ENGINEERING, and as the design is substantially the same as hitherto, it need not be repeated here. They are most versatile machines and although used mainly by orchardists and market gardeners, they are now becoming popular on farms generally as they can be usefully employed in cultivating plots of land in isolated positions difficult to work with a tractor.

FIG. 9.

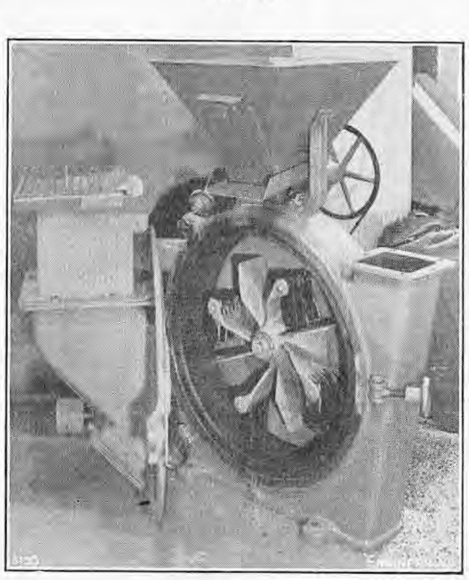


FIG. 10.

FIGS. 9 AND 10. "KAYBEE" HAMMER MILL; T. R. WALKER.

INTERNATIONAL CONFERENCE ON ABRASION AND WEAR.

(*Continued from page* 725.)

WE continue below our report of the International Conference on Abrasion and Wear that was held in Delft, Holland, on November 14 and 15. The previous instalments dealt with the proceedings on November 14, and we now proceed with the report of the papers and discussions which occupied the morning of November 15, the first paper (the fifth in the complete programme) being that of Dr. N. A. Brunt, of the Paint Research Institute at Delft, on "The Abrasion Resistance of Paints."

ABRASION RESISTANCE OF PAINTS.

The abrasion resistance of paints and lacquers, said Dr. Brunt, could be assessed by the reduction in gloss or the decrease in weight when they were exposed to the impact of a column of falling abrasive, such as sand, or to rubbing by hard, coarse and solid particles. A system in which the nature of the abrasive and the mechanical properties of the surface were idealised provided a working hypothesis for a new theoretical and experimental approach. The abrasive was assumed to consist of small spheres, uniform in mass and diameter, which dropped with identical velocity on to the painted surface. Normal and tangential components of the resulting impulse would produce stresses in the surface; at least, for a short time. The occurrence of fracture would depend essentially on the balance between the impact forces and the mechanical properties of the paint layer. Two classes of materials, with either ideally elastic or retarded elastic properties, could be distinguished. In the first, those with ideally elastic properties, a high probability of fracture resulted from the combination of a high modulus of elasticity with a low value for the ultimate tensile strength. The combined effect of the impact of all the spheres was to produce a network of cracks, leading ultimately to a loss of material, i.e., abrasion. In the second category, a low modulus, either of a visco-elastic or an ideally elastic body, prevented the development of high temporary local stresses, because the material deformed readily under the influence of the impacts. The likelihood of the occurrence of fractures in such paints was therefore small.

Reduction in gloss without a loss of material, Dr. Brunt continued, could result from plastic flow of the paint, repeated impacts of the abrasive causing irreversible plastic deformations of the surface, which thus lost its smoothness. Such considerations made it possible to predict the abrasion resistance of lacquers of defined composition when the fundamental mechanical properties of the basic material were known; this had been confirmed by a number of experiments. The mechanical behaviour and the abrasion resistance of a series of nine nitrocellulose lacquers had been ascertained, the properties being varied by using polymers of different molecular weights and by varying the proportions of the pigments and plasticisers. This idealisation of the abrasive process lost its validity, however, when the dimensions of the abrasive spheres were so small as to be approximately molecular. The notion of stress was necessarily associated with volume elements which were infinitely small as compared with macroscopic dimensions, but which contained, nevertheless, an infinite number of molecules. It seemed probable that very small particles would have a polishing effect on the paint. Soft materials, such as textiles, might be compared with polishing paste, containing particles of very small size.

Dr. R. Houwink, who opened the discussion, said that he could not agree entirely with Dr. Brunt's implications that the ideal anti-abrasive material should combine the high tensile strength of glass with the low modulus of rubber. The tensile strength of glass was about 600 kg. per square centimetre, and that of rubber was only 200 kg. per square centimetre; but rubber would extend to ten times its unstressed length, so that its ultimate tensile strength was about 2,000 kg. per square centimetre, or four times that of glass. He could

EXHIBITS AT THE SMITHFIELD SHOW, EARL'S COURT.

(*For Description, see Page* 757.)

Fig. 11. International Tractor Fitted with Rotary Hoe; Rotary Hoes, Limited.

Fig. 12. "Monarch" Light Four-Wheeled Tractor; Oak Tree Appliances, Limited.

Fig. 13. Universal 18-Ft. Elevator; A. B. Blanch and Company, Limited.

Fig. 14. "Gem" Series IV Rotary Cultivator; Rotary Hoes, Limited.

Fig. 15. "Bantam" Rotary Hoe Fitted with Hymatic Compressor; Rotary Hoes, Limited.

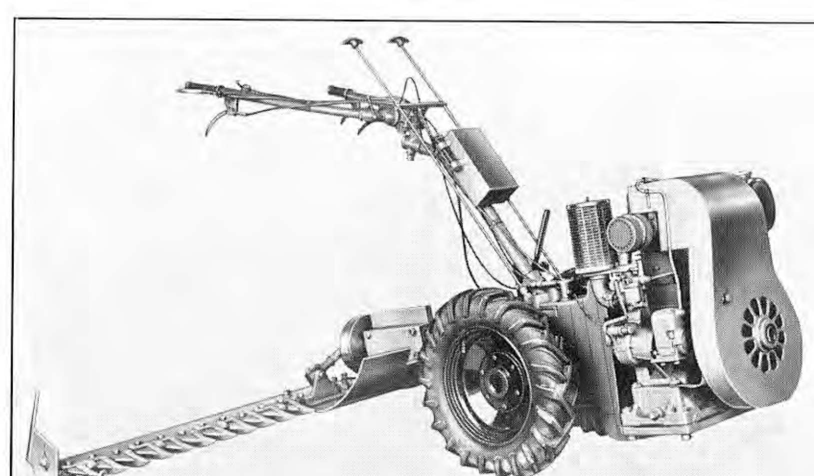


Fig. 16. Cultivator Fitted with Mowing Attachment; Clifford Aero and Auto, Limited.

not agree, either, that a decrease of the modulus always produced a high abrasion resistance; for certain cases, such as those mentioned by Dr. Brunt, it might be true, but in others it was the reverse. For example, carbon black in rubber increased the modulus of elasticity and the abrasion resistance.

Dr. J. Hoekstra, who followed, thought that the author's approach to the problem was of great value, because it was essential to go into the physics of such complicated matters; even in the case of impact abrasion, where the temperature effects at the point of impact probably had much less influence than in the case of abrasion by friction, great care should be taken. The breaking strength of a material was governed more by the occurrence of flaws in the test strip, or at the corners of the strip, than by lack of cohesion in the material itself. Generally speaking, it was not known what loads materials would withstand under the stresses acting in the complicated conditions of compression, deformation, heating and relaxation which occurred during abrasion. Lacquers baked on to copper wire at 300 deg. C. had been found to have an extension of 50 or 60 per cent. when the same lacquer, in sheet form, gave only 1 to $1\frac{1}{2}$ per cent.

Dr. W. Späth observed that it was necessary to distinguish between a component of the velocity of the falling carborundum grain which was perpendicular to the surface of the test specimen and one that was parallel with it. The total abrasion, therefore, was very complicated, and, he suggested, it should be useful to repeat the experiments with different angles of the impinging flow.

Professor A. van Rossem said that Dr. Brunt had shown the abrasion resistance to depend on the modulus of elasticity, but, in his own opinion, the important factor was not so much the modulus of the material as the resilience; rubber showed a very high abrasion resistance against a sand blast for this reason, and not because of its softness. The case of an asphalt road was different; in that case, the small mount of abrasion did not result from the qualities of the bitumen, which was merely the adhesion material, but from the hardness of the stones embedded in it.

Mr. J. Heyboer thought it possible that Dr. Brunt's conclusion regarding the connection between abrasion resistance and the modulus of elasticity might only hold in the case of extreme softening. At the Plastics Research Institute at Delft a study had been made of polymethylmethacrylate, plasticised with dibutylphthalate. In that case, abrasion by impact increased while the modulus of elasticity decreased; but abrasion by friction also increased with the percentage of plasticiser, though the elasticity then remained sensibly uniform. Dr. F. Schwarzl, also of the Plastics Research Institute, followed Mr. Heyboer's remarks with an inquiry whether the abrasion of Dr. Brunt's test specimens was not started by local heating on impact, since carborundum had a high kinetic energy in relation to its particle size.

Mrs. M. Leitner suggested that abrasion alone was not a sufficient test of paint; weathering also should be considered. This applied especially to the hard outer layer. The age of chemically drying paints determined the thickness of the outer layer and therefore influenced the results of abrasion tests. Bituminous lacquers were not suitable for outdoor use because of their poor resistance to weathering. She asked whether the relation between weathering and abrasion resistance had been investigated.

Dr. F. T. Barwell said that the author had emphasised the connection between abrasion resistance and a low modulus of elasticity, but he had referred only incidentally to tensile strength. Did he consider the ratio $\frac{f}{E}$, or the extension at yield to be the important factor, or was the conventional proof resilience, $\frac{1}{2}\frac{f^2}{E}$, the appropriate criterion? The latter view was attractive, as it represented the amount of energy that a material could store without permanent change. The conception could only be approximate for the materials under discussion because, as had been said earlier, stress-strain relationships were not linear, but were complicated functions of time and temperature. It was possible, however, to consider reversible and irreversible effects. Did the author think that plastic flow—an irreversible absorption of energy—played any part in abrasion resistance? A feature of rubber which might contribute to its abrasion resistance was the great hysteresis revealed by the stress-strain loop.

Dr. Brunt, replying to the discussion, said that clearly he had underestimated the ideal properties of rubber; from the standpoint of Dr. Houwink's theory, rubber was perfectly ideal. He emphasised, however, that the views he had expressed represented only a very rough approximation and accounted only for great differences in abrasion resistance. Dr. Hoekstra was right in his warning to be careful in drawing conclusions; measurements of ultimate strength were always difficult and would exhibit a wide spread in the values of the stresses at which breakage occurred. It seemed likely, however, that the spread would be smaller when the rate of extension increased. He agreed with Dr. Späth's objection; in the experiments described, the abrasion was not the result of pure impact. Nevertheless, there was a great difference in abrasion by friction, because the motions parallel to the surface were restricted within very narrow limits, which was never the case in a pure friction apparatus. In reply to Professor van Rossem: the notion of elasticity must have an exact sense, and the only way to arrive at a definition was to make use of the conception of the modulus. A low modulus, therefore, was identical with a high "elasticity," using the term in the sense that Professor van Rossem had done. The high abrasion resistance of an asphalt road, he maintained, was due to the bitumen and not to the stone filling of the asphalt.

Mr. Heyboer had suggested, Dr. Brunt continued, that the conclusion expressed in the paper only held good in the case of extreme softening. This was possible, and he again pointed out that the whole theory was only a very rough approximation. The measurements he had made, however, did give an indication in that direction. The lacquers containing no plasticiser and those with 30 per cent. showed little or no difference in abrasion resistance; in fact, in one case a decrease was observed. The temperature rise on impact, referred to by Dr. Schwarzl, was only about 2 deg. C., and in any case the temperature rise could only be very brief. In reply to Mrs. Leitner: the relations between mechanical properties and, respectively, the ageing and weathering of the varnishes had not been investigated. It was important to understand the mechanical properties and to make clear the relations between them and the fundamental physical quantities; but weathering was really another subject, and was partly a chemical effect. With regard to Dr. Barwell's point: as he viewed the matter, abrasion was connected with rupture, and rupture would occur only when the actual force exceeded the ultimate value of the stress that the material could withstand; therefore, the value of f must not be compared with the modulus E, but with the actual stress, which was not only a function of E, but also of the strain. All that he had emphasised was that, for a given strain, the stress would remain small if the value of E was low. Of course, a strong viscous flow—i.e., an irreversible deformation—was always associated with a low modulus, and therefore with a high abrasion resistance.

A vote of thanks having been accorded to Dr. Brunt, the chairman (Dr. H. C. J. de Decker) called upon Dr. A. Schallamach, of the British Rubber Producers' Research Association, to deliver his paper on "Elementary Aspects of Rubber Abrasion."

THE ABRASION OF RUBBER.

Dr. Schallamach, introducing his paper, remarked that Mr. J. M. Buist had recently listed 21 abrasion machines for testing tyres, none of which told the real story; there was, in fact, no substitute for the road test. In the first part of his paper, he proposed to discuss a very simple case of abrasion, namely, the effect of scratching rubber with a needle. The second part would deal with the so-called "abrasion pattern" that was found on abraded rubber surfaces, and which consisted of an array of approximately parallel ridges, oriented at right angles to the direction of motion. The scratching experiments were carried out under various conditions of normal load on the needle and at various velocities, provision having been made to record instantaneously the tractive force on the needle. The traces produced, and the corresponding records of tractive force and time depended markedly on the nature of the compound under investigation. The traces on pure gum vulcanisates, in particular, were always discontinuous, the time dependence of the tractive force lying on saw-tooth curves. The traces on carbon-loaded samples of the tyre tread type, however, were continuous, and the tractive force was subject to much smaller fluctuations than in the case of the pure gum compounds. The harder the rubber, the greater was the damage caused by the needle. The surface damage on all types of rubbers was characterised by the fact that small pieces of partly-detached rubber were found in the wake of the needle and these were easily removed when the surface was attacked again. It had been found possible to express the results of the experiments qualitatively in terms of the hardness, friction and tear-resistance of the samples.

The abrasion pattern, Dr. Schallamach continued, appeared both on samples abraded in the laboratory, and on tyres; in the latter case, the ridges were usually oriented at an angle to the direction of motion of the vehicle. A cross-section through the abraded rubber surface showed that the profile of the ridges constituting the pattern was asymmetrical, and it was possible to identify the direction in which the abrasive has moved in relation to the abraded surface. Certain other properties of the abrasion pattern had been ascertained in the laboratory, and it had been discovered that, during abrasion, the pattern moved as a whole in the same direction as the abrasive. The pattern had provided important clues to the conditions under which abrasion occurred on the road; most probably, it originated as a direct consequence of the high elasticity and the high coefficient of friction of rubber.

The first speaker in the discussion was Dr. G. J. van der Bie, who said that the abrasion of rubber was governed by four factors, namely, the tear strength (the result of cross-linking and the presence of an active filler); elasticity (again a result of cross-linking and an active filler, and influenced by the molecular structure of the rubber); the dissipation of heat, which depended on the design of the tyre and the heat conduction of the compound used; and the avoidance of degradation, especially by oxidation. The work of Dr. Schallamach concerned only the first two of these, but the others were important and should not be disregarded.

Dr. G. J. van Amerongen agreed with Dr. van der Bie that the degradation of rubber was liable to be overlooked. Eventual oxidation was inevitable, but, he asked, did rubber ever reach a temperature likely to cause degradation? Dr. Bowden had shown that, during friction, a considerable rise of temperature could be expected in rubber; this rise might be especially high at critical spots in the rubber, and temperatures up to 600 deg. C. had been mentioned. It seemed probable, however, that rubber as such would never reach such a temperature; even at temperatures of 200 to 300 deg. C., oxidation and pyrolisis of the rubber at such hot spots would have broken down the rubber molecule completely. A less complete breakdown might lead to the formation of a thin plastic top layer on the abraded surface, a condition which would tend to produce a favourable coefficient of friction; could the moving of ridges, to which the author had referred, be explained by the presence of such a plastic layer? Even if a major breakdown were avoided, the development of heat in the abrading surface must weaken the rubber in the long run, because of oxidation; recognition of that effect would readily explain the superior abrasion properties of tyres made of rubber loaded with furnace blacks, compared with those containing channel blacks, the rate of oxidation of rubber containing furnace black being much lower than that of rubber made with channel black. At the higher temperatures (as would appear in due course from the paper to be given by Dr. R. D. Stiehler), tyres made with synthetic rubbers of the GR-S type showed a better abrasion performance than tyres of natural rubber. Perhaps one reason for this better performance might be that the synthetic rubbers had a better oxidation resistance than the natural rubbers.

Dr. E. de Meeus thought that the needle test described by Dr. Schallamach was likely to develop into a very sensitive test: its application to the outside and inside of a tyre should reveal any differences in the curing of the rubber. There was another form of needle test, in which the hundreds of "needles" represented by a corded cloth, mounted as a buff on a wheel, were used to abrade a rubber sample. The material removed varied in size from dust to small lumps, the condition of the abraded particles indicating the state of curing between one part of a tyre and another. As a tyre must grip the road, a certain amount of useful wear must be allowed. In his experience, however, this did not result in the production of any regular pattern in straightforward running, although a pattern was quickly produced as a result of wheel-spin, high-speed cornering, heavy braking, or poor wheel alignment. He asked whether the presence or absence of pattern had any real significance.

Mr. G. L. Hammond regretted that no more had been done during the conference to interpret abrasion and wear in terms of changes in molecular structure. Both diamond and raw rubber had outstanding resistance to abrasion. Both were polymers, but whereas diamond was a perfect three-dimensional cross-linked polymer, raw rubber was made up of long randomly coiled or kinked chains; therefore diamond was rigid, while raw rubber was non-rigid and thermoplastic. It seemed reasonable to assume that the abrasion resistance of diamond could be attributed to its very strong internal structure, every individual carbon atom being linked by primary bonds with four other carbon atoms; to remove a single atom, it was necessary to apply enough energy to break all of these bonds. On the other hand, the abrasion resistance of raw rubber might be attributed to its ability to flow and deform, to stretch and, subsequently, to return to its original shape; i.e., the individual chain was capable of accepting and storing a considerable amount of energy, the energy of impact being spread over many carbon-carbon bonds along the chain. If, however, the velocity of impact, or frequency, was very great, there was insufficient time for the energy to be shared along the chain and the maximum strain might fall entirely on the single bond between two carbon atoms. In such circumstances, the plastic properties of rubber disappeared and it became a harder and more rigid material, which would be expected to be relatively brittle and to have much lower abrasion resistance. The effect of oxygen on this mechanism of primary bond stability was also in need of examination. Did oxygen, in some way, initiate the break in the carbon-carbon bond, or did it merely react with the end carbons after the chain was ruptured? If some mechanism such as he had postulated should be true, it would be reasonable to expect an energy of activation to exist for abrasion, since it was clear that either a single bond or a chain could accept a certain amount of energy without breaking. Only when that critical figure was exceeded did chain rupture occur.

Dr. S. M. Hagman asked whether, in practice, crushing was not an important cause of wear. Admittedly, crushing was not wear in the true sense, but it was difficult to say how much of the practical wearing was due to crushing and how much was real wear. If the energy applied to a material were more than the resilience of the material could absorb, the material would break down; for example, a thin rubber heel would abrade more than a thick one. The amount of energy applied to a rubber heel or a tyre could be ascertained, and the capacity for absorbing energy could be measured by the resilience of the rubber; but it was hard to say how much of that rubber was absorbing the energy when the time of the elastic deformation was so short, and the energy absorption could not (to use a somewhat unphysical expression) spread through a greater amount of the rubber. He thought that crushing phenomena played a large part in wear, and especially in the initial stages of wear; and that it was after the material had been thus weakened that the rate of wear increased. Professor Blok's reference to the overstressing of materials seemed to indicate that he also held that view; and it might be that the phenomena associated with the breaking down of wool and cotton, described by Dr. Salomon, were of a similar nature.

Dr. Schallamach, replying to the discussion, said that he had deliberately confined his investigations to the mechanical aspect of rubber abrasion, but he appreciated that the wear of tyres was influenced by a number of other factors—heat build-up, oxidation, etc.—such as had been mentioned by Dr. van der Bie and Dr. van Amerongen. He thought, however, that, while these factors might affect the rate of abrasion, they would not necessarily modify its mechanism. In reply to Dr. van der Bie's query: the harder compound had the lesser tear resistance. Dr. de Meeus's interesting observations on the debris produced by buffing with a coarse cloth were supported by ordinary abrasion experiments in which not only the size but the shape of the abraded particles depended on the nature of the rubber. The abrasion pattern on tyres was not the result of peculiar driving conditions; it might not always be conspicuous, but it could always be seen under suitable conditions of lighting. It might become blurred after a prolonged period of wet weather. In reply to Mr. Hammond: the rate of temperature rise in abrading the rubber was not high enough to suggest an activation process. He did not think that crushing was a major source of abrasion, as suggested by Dr. Hagman; moreover, crushing was a random effect and therefore could not be responsible for the abrasion pattern, which must be due to some co-operative effect. He agreed with Dr. Hagman, however, that dynamical properties had to be taken into consideration when going into the details of the abrasion process in rubber.

The Conference then adjourned until the afternoon.

(To be continued.)

LABOUR NOTES.

COMMENTS on the increasing cost of maintaining trade unions are contained in the December issue of *Labour*, the official monthly journal of the Trades Union Congress. In an article on union membership and finance, it is stated that the amount of money spent on the administration of these organisations far outweighs all the benefits paid to members from the unions' funds. Some union executive committees, the article continues, have found it necessary to emphasise how the cost of running their unions is mounting year by year, while the subscription remains unchanged.

Labour also suggests that the trade unions should show more enterprise in using the very substantial funds, which they have accumulated through the years, than they have done. Larger sums should be expended on education, research and training. Although some of the larger unions are already proceeding along these lines, much remains to be achieved. The journal considers that the smaller unions, with only limited funds at their disposal, could embark on similar activities and obtain the required money by acting in combination through their federations. It recognises that a large proportion of the total funds in the hands of the unions is held against the possibility of their having to make cash payments to their members, but states, in conclusion, that the main weight of the evidence supports the view that the advance of the trade-union movement, as a whole, is no longer handicapped by poverty.

Funds in the possession of trade unions in Great Britain at the end of 1940 totalled 24,708,000*l*. and steadily increased during the war years and subsequently, until, at the end of last year, they amounted, in all, to 62,150,000*l*.; an increase of 150 per cent. during the ten years. According to the annual return of the Chief Registrar of Friendly Societies, published last month, there were 416 trade unions on his register at the close of 1940 and the same number at the end of last year. In a covering note to his statistical summary, the Registrar states that it is estimated that the membership of the registered unions of employees now represents about 90 per cent. of that of the whole of the trade-union movement in Great Britain. The 416 unions registered in 1940 had a total membership of 5,362,000 men, women and juveniles, and a combined income of 9,918,000*l*., of which 9,041,000*l*. was contributed by the members and 877,000*l*. was derived from investments and other sources. In 1950, the total membership of the 416 unions then registered was over 7,947,000 persons. The unions received a combined income, during that year, of 17,624,000*l*., of which 15,721,000*l*. was obtained from members' contributions and 1,903,000*l*. from other sources, including investments.

Expenditure by the registered trade unions in Great Britain amounted to 14,026,000*l*. during 1950, or nearly double the outgoings incurred during 1940, which totalled 7,706,000*l*. The largest single item in each of these years was that recorded by the Registrar under the heading of working expenses. The cost of administering the unions—salaries, insurance, travelling, telephone charges, printing and stationery, maintenance of premises and so on—amounted in all to 8,226,000*l*. during 1950, compared with an aggregate of 3,486,000*l*. during 1940. Expenditure by the unions from their political funds increased from 102,000*l*. during 1940 to 451,000*l*. during 1950 and was even higher, at 517,000*l*., during 1949. Unemployment benefits, which absorbed 797,000*l*. during 1940, cost the unions only 163,000*l*. during 1950, but benefits paid out in the course of industrial disputes increased from 55,000*l*. in 1940 to 244,000*l*. in 1950.

Trade unions in the engineering, shipbuilding, metal-manufacturing and vehicle-building group of industries declined in number from 69 in 1949 to 68 in 1950, but the total number of members increased from 1,631,361, in the former year, to 1,638,856 in the latter. The total income of this group of unions amounted to 4,860,000*l*. during 1950, of which some 4,301,000*l*. was derived from the subscriptions and fees of members and 559,000*l*. from investments and other sources. Expenditure aggregated 3,818,000*l*., leaving a balance in hand of more than one million pounds on the year's working, and, in fact, the total funds of these unions jumped from 18,471,000*l*. at the end of 1949 to 19,513,000*l*. at the end of 1950. During the intervening twelve months, the unions spent 75,000*l*. on unemployment benefits, 58,000*l*. on dispute benefits, and 973,000*l*. in superannuation payments to its members. Working expenses cost another 1,733,000*l*.

Federations of trade unions in Great Britain and Northern Ireland numbered 52 at the end of December, 1950, there being no change in the total at the end of 1949. The *Ministry of Labour Gazette* for November reports that, although a large proportion of trade unions are affiliated to federations, some are not linked together in this manner, while others are affiliated in respect of only a part of their total membership. On the other hand, many trade unions, or particular branches of trade unions, are affiliated to more than one federation. It may be mentioned that there were 96 associations of employers registered with the Chief Registrar of Friendly Societies at the close of 1950, against 97 at the end of 1940. The memberships of these employers' associations increased from 53,727 in 1940 to 116,703 ten years later. In 1950, their total income amounted to 421,000*l*., and their outgoings to 393,000*l*., of which 313,000*l*. was accounted for by working expenses.

Negotiations between officials of the Engineering and Allied Employers' National Federation and the five unions representing women employees in the engineering industry took place in London on Tuesday last and were in progress for several hours, but without any settlement being reached. The unions had previously presented demands for a weekly increase of 20*s*. in the wages of women engineering operatives and it is understood that the employers had offered to make an advance of 10*s*. This was rejected by the unions, apparently on the ground that it was less in amount than the 11*s*. a week recently awarded to men engaged in the industry. The unions are insisting that any increase granted to women should at least equal that conceded to the men.

Some 170,000 women operatives are employed by engineering firms which are members of the Engineering and Allied Employers' National Federation, including many engaged in the production of electrical appliances and wireless sets. As, however, many companies outside the Federation pay their employees in accordance with the wage rates determined by the Federation, the total number of women involved in these wage negotiations is considered to be in excess of 400,000. It was stated after the discussions last Tuesday that no arrangements had been made for any further meeting between the two parties.

Employees at three factories in the Merthyr Tydfil area, South Wales, were concerned in a one-day strike on Tuesday last, stated to be caused by the refusal of an operative at one of the factories to join a trade union. The works are mainly concerned in the production of washing machines, most of which are sent overseas. After a mass meeting on Tuesday night, it was decided to resume work at full strength on the following morning, in order that negotiations on the difficulty might be commenced between the unions and managements involved.

MEASURING STRESSES IN AIRCRAFT TURBINES.

Fig. 1.
MID-CHORD.

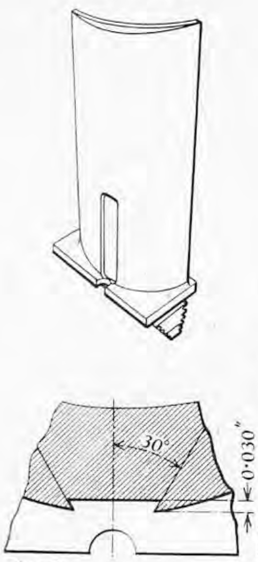


Fig. 2.
TRAILING EDGE.

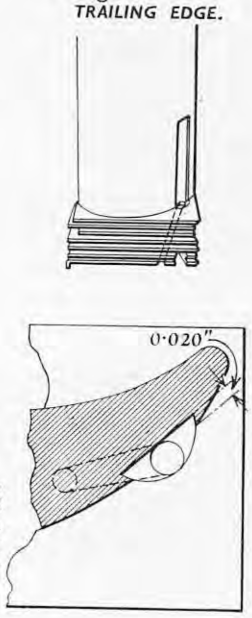


Fig. 3.
TRANSDUCER AND BALL CLAMP.

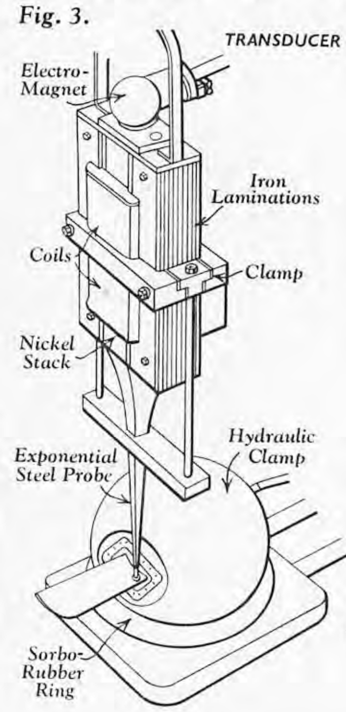


Fig. 4.

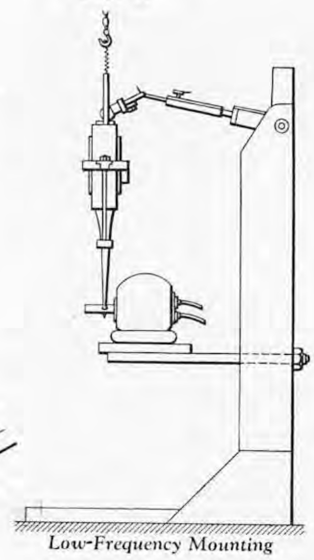
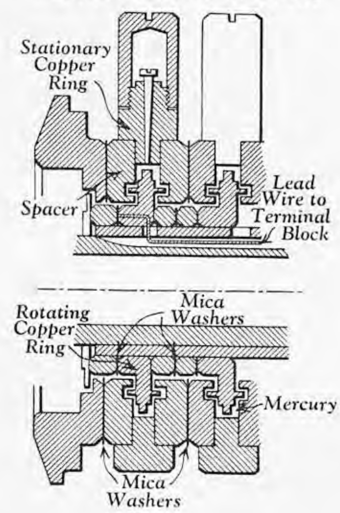


Fig. 5.
MERCURY SLIPRING ASSEMBLY.



"ENGINEERING"

FIG. 6. INTERIOR OF VIBRATION-MEASURING CARAVAN.

MEASURING STRESSES IN AIRCRAFT TURBINES.*

By DENIS A. DREW, B.Sc., A.M.I.Mech.E., A.M.I.E.E.

IN studying the cause of turbine bucket failures on aircraft gas turbines on the test-bed and in flight, Messrs. Rolls-Royce, Limited, decided that the most practicable way of investigating the stresses was by wire-wound strain gauges on the buckets themselves. A suitable means of attaching the gauges so as to withstand temperatures of the order of 1,200 deg. F., and centrifugal forces equal to 20,000 times the weight of the gauge, was found to be the Quigley Company's high-heat paint. This cement has excellent strength in shear, even at high temperatures. The adhesion to Nimonic surfaces is also excellent in shear, but is not so good in tension. The attachment of gauges or other connecting leads to circumferential surfaces has therefore been avoided.

* Paper entitled "The Measurement of Turbine Stresses in Aircraft Engines in the Laboratory, on the Test Bed, and in Flight," presented to the Society for Experimental Stress Analysis on November 30. Abridged.

The gauges are mounted in undercut recesses, as shown in Figs. 1 and 2, partly to prevent the gauge from interfering with the gas flow round the bucket and partly to assist in withstanding centrifugal forces. The "platform" of the bucket is drilled, and the nickel leads are threaded through the holes inside ceramic tubing, as used for thermocouples. For the gauges, Nichrome wire of comparatively heavy gauge, 0·002 in. diameter, is used, which has enabled a long life of the gauges to be obtained, of the order of 10 hours, including 20 or 30 starts. A large number of tests could therefore be carried out on the same gauge and relatively good repeatability could be obtained in the test data.

It will be observed that in Fig. 1 the bucket is shown slotted in the mid-chord position and, in Fig. 2, in the trailing edge. The mid-chord position is more sensitive to flap modes and the trailing edge to torsional and higher-order modes of vibration. The work has been carried out largely with the buckets gauged in these two standard positions, partly because the temperatures and centrifugal forces near the root of the bucket are less than at other positions, and partly because it is easier to identify the mode of vibration of a bucket in the engine with the vibration of a similar bucket in the laboratory if the stresses in two different gauge positions are available. The frequencies cold and the frequencies in a running engine may differ by 20 per cent., due to temperature effects which vary with the elastic modulus and the density of the bucket material. If the temperature is not accurately known, and the bucket has a number of modes whose frequencies vary but little, then it is a great advantage to know the ratio of the stresses in the two positions for the mode to be identified.

In the laboratory, it is relatively easy to measure the ratio of the stresses at the gauge position to those at other positions in the blade, such as the usual point of failure, using ordinary Bakelite strain gauges or stress lacquer. In order to do this, however, it is necessary to impart considerable vibratory energy to the bucket. Although this presents no difficulty when considering the lower-order modes, such as first and second flap and torsional modes, it is difficult to provide sufficient vibratory energy at frequencies greater than 10 kilocycles per second by conventional electromagnetic means. In order to investigate the stress distribution in buckets over the relevant frequency range, aluminium-alloy model blades of five times the normal size were constructed. The density and elastic modulus of aluminium are less than those of Nimonic in very nearly the same proportions, so that the natural frequencies of these large model blades were almost exactly one-fifth of the frequencies of the standard blades. They could, therefore, be vibrated by ordinary electromagnetic vibrators up to considerable stresses and, owing to the low elastic modulus, the strains would be large. Small gauges could be used and the exact position of maximum stress in the higher-order modes could be investigated with accuracy. The large-scale blades are, however, costly to manufacture.

Although the frequency of the blades resonating in the 48th-order mode in an engine vibrate at 11 kilocycles per second, they must be vibrated at about 13,200 cycles per second cold in the laboratory to have the same nodal and stress diagrams. It would be very difficult to obtain sufficient energy to fail a bucket of normal size by ordinary electromagnetic methods of excitation at 13,200 cycles per second. It would also be difficult to vibrate a normal bucket at sufficient amplitude to permit an investigation of stress distribution by means of strain gauges. In order to facilitate the problem, therefore, a number of buckets were made in cast aluminium, the fatigue strength of which was about 25,000 lb. per square inch, so that buckets could be failed in the laboratory at a much lower stress than would have been possible if Nimonic buckets had been employed. The elastic modulus of the alloy was also low enough to increase the signal obtained from a strain gauge. As in the case of the large-scale bucket, the resonant frequency is almost unchanged.

From information supplied by the British Admiralty Underwater Detection Establishment at Portland, magneto-strictive transducers were developed which have been used to fail a number of Derwent 5 turbine buckets, from which it has been established beyond any doubt that it is the 48th order (i.e., the nozzle guide-vane order) vibration which was responsible for flight failures. The type of magneto-strictive transducer used is shown in Figs. 3 and 4. The magneto-strictive element consists of a stack of commercially-pure nickel strips cemented together with Bakelite cement. The length of this stack changes with the magnetic flux passing through it. This changing flux is provided by a winding energised by a beat-frequency oscillator and a 1,300-watt amplifier. A conventional laminated-iron circuit is employed. Polarising current supplied from a battery via a choke may be supplied through a separate winding, or through the alternating-current winding provided that the transformer secondary circuit is blocked against direct current by a suitable capacitor. In order to obtain the greatest possible transfer of energy into the transducer for a given size of amplifier it is necessary to tune the circuit. This may conveniently be done by adjusting the blocking capacitor. The nickel stack must be tuned so that its resonance in axial vibration approximates to the frequency required, in this case 13,200 cycles per second. Its length was therefore 7·04 in., the speed of sound in nickel being 4,900 m. per second. The inertia of the stack itself is used to take the reaction from whatever load is applied.

The maximum stack movement is about 0·005 in. at each end. If the stack is coupled directly to a turbine bucket, insufficient movement will be imparted to the bucket to induce stresses of sufficient magnitude to cause failure, or to permit stress-distribution analysis by gauges or stress-coat processes. One square-inch section is capable, however, of exerting very large forces provided that it is coupled efficiently to the turbine bucket. To amplify the movement, therefore, an exponential probe, attached to the end of the nickel stack as shown in Fig. 3, was employed. The centre of gravity of the probe (its movement node) is constrained towards the centre of the stack by thin steel ties. The movements of the two ends of the probe are in inverse ratio to their areas. For minimum losses, the joint face between the stack and the probe must be at a force node, i.e., a movement antinode, and therefore the stack must be tuned (by its length) to the required frequency. For maximum energy transfer to the bucket, the motional impedance of the load must match that of the stack and probe assembly.

The signal from the gauges is brought out through mercury slip-rings mounted at the front end of the engine. It is not necessary to mount the balancing gauge on the rotating system, and six gauges can be run with 12 rings without having to resort to a common ring, which has the objection that a fault in one circuit is liable to give a false reading in another. The rings consist of copper discs, amalgamated with mercury at their outer edges, running in annular spaces between stainless-steel spacers which are insulated by mica, as shown in Fig. 5, on page 761. The clearances are kept low since, with the rings stationary, the mercury is held in position only by gravity and capillary attraction. At speed, the centrifugal force acting on mercury is sufficient to make leakage impossible, even in the presence of considerable vibration. The wires from the turbine disc are brought right through the centre of the rings, which are driven by a splined shaft, and are soldered to lugs in a rotating terminal board. Further leads are soldered to these lugs connecting them to the actual rotating rings. In this way a large number of gauges may be fitted to an engine, although only six may be connected up at one time. When sufficient test data have been obtained from one gauge, it is possible to change over to another in a very short time after the engine is stopped. The rings are made up in sets of six, but two assemblies may be driven in line. Normally, work is carried out with not more than one ring unit supplying three gauges via six rings. Working with a larger number of channels would considerably increase the analysing and other problems. Without very special magnetic screening the amplification is limited by the generation of electro-magnetic forces in any loops of wire rotating on the engine rotor in stray magnetic fields. To reduce this effect to a minimum, the slip-rings are made of non-magnetic materials and pairs of wires are twisted together as far as is practicable so as to reduce the area of loops to the minimum. Any "noise" due to this cause occurs at the first engine order.

For investigating the lower-order vibrations of buckets, such as the first and second flexural and torsional modes, Rolls-Royce use a conventional continuous-film camera running up to 450 in. per second. Where higher film speeds are required, a drum camera developed by Messrs. Rotol Airscrews, Limited, is used, which gives excellent results up to speeds of 900 in. per second on 70 mm. film. It may be automatically reloaded at speeds up to about 700 in. per second. It is capable of resolving frequencies up to 35 kilo-cycles per second. For resolving the higher-order modes of turbine-bucket vibration, however, there is a serious objection to the direct use of any form of camera. During a gradual acceleration of the engine a burst of high stress may be of only 50 milli-

MEASURING AIRCRAFT-TURBINE STRESSES.

Fig. 7. SIMPLIFIED WIRING DIAGRAM OF AIRBORNE EQUIPMENT.

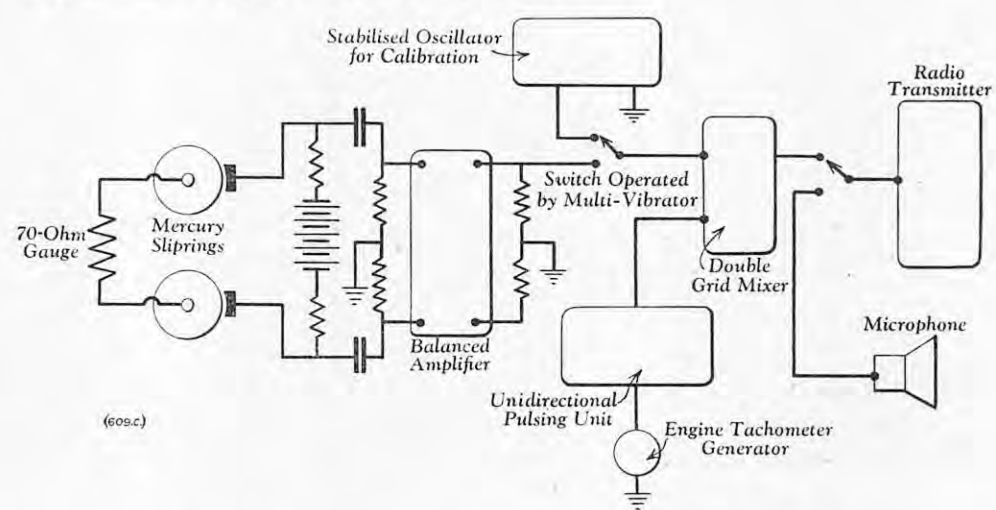
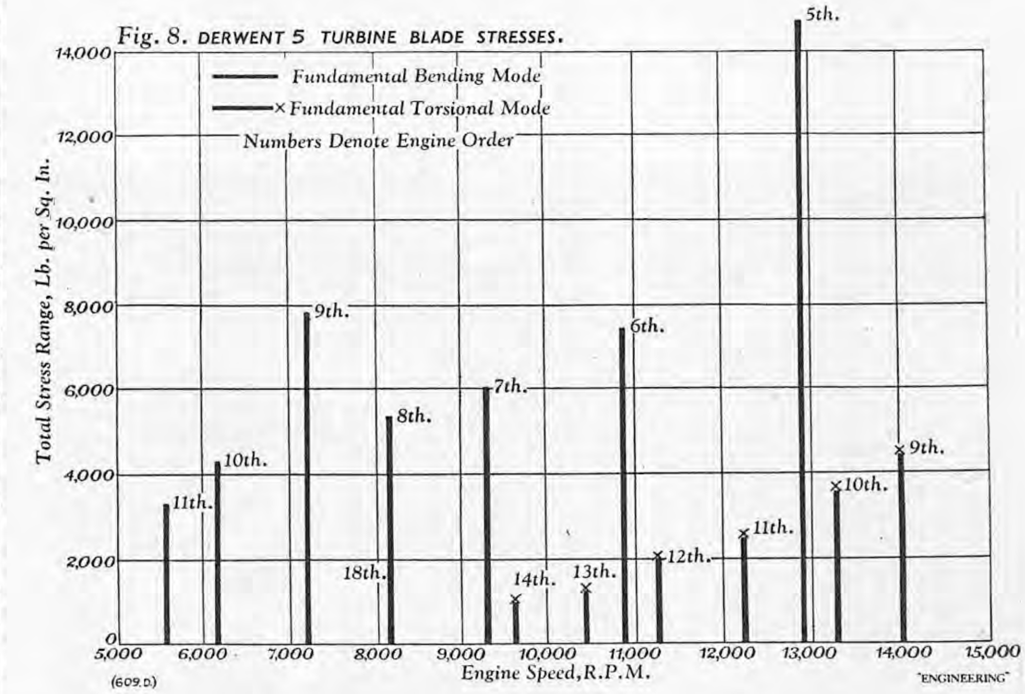


Fig. 8. DERWENT 5 TURBINE BLADE STRESSES.



seconds duration. It is difficult to maintain engine speeds at the peak on the test bed; it is quite impossible in flight. Many attempts have been made to photograph the peak of a burst of stress on continuous-film and drum cameras, but since it is not practicable to accelerate more than, say, 100 ft. of film sufficiently rapidly to enable frequencies in the ultrasonic range to be resolved, it is always difficult to make quite certain that the operator really has exposed the film at the instant of maximum stress. This difficulty has been overcome by recording the strain-gauge signals on a magnetic-tape recorder with the tape running past the recording head at 30 in. per second; by this means, fairly good response up to something a little higher than 15 kilocycles per second can be obtained. The recording and playback amplifiers are loaded to replay with the tape running at 15 in. per second. The trace in a cathode-ray oscillograph connected to the replay amplifier of the recorder is photographed in a continuous-film camera at medium speed, say, 300 in. per second. So long as the operator can observe the nature of the signal on his replay monitor-tube it is quite satisfactory to postpone taking measurements until later, when the tape is run past the replay head at reduced speed.

In order to obtain the greatest possible reliability in service from electronic measuring equipment, Rolls-Royce have installed non-portable equipment in a large caravan. Fig. 6 shows the interior; the equipment comprises three-channel strain-gauge equipment, including attenuation switches for the strain gauges and three balanced amplifiers having a voltage gain of 5×10^5. The amplifiers may be coupled to a three-tube oscillograph and to small monitor oscillographs so that photography of the main oscillographs is not disturbed when it is necessary to observe the traces. All the above equipment is made in the Rolls-Royce works. A three-channel direct-coupled amplifier is provided, capable of frequency modulation by reactance-conscious pick-ups. The carrier frequency is 2 mega-cycles. Any combination of these channels may be coupled to the oscillographs. (This equipment is not used in connection with the measurement of bucket stresses.) There is a crystal-controlled timing marker, and an engine tachometer and facilities for displaying revolution marks in the cathode-ray oscillographs, as well as timing marks on small argon lamps which come within the field of either a high- or medium-speed camera.

Most of the flight testing has been carried out in Gloster Meteor aircraft with no accommodation for an observer or for a tape recorder; the amplitude of the carrier wave of the normal aircraft transmitter has therefore a signal proportional to stress. The danger of high-frequency fading, and the tendency for a reduction in signal strength with the distance between the aircraft and the receiving equipment, make it imperative that a calibrating signal is provided. An arrangement which has proved to be very successful is to carry in the aircraft a stabilised Hartley oscillator working at a frequency near to that of the stresses in which we are particularly interested. The stress signal is punctuated five times a second by the short bursts of the calibrating signal from the oscillator through a mechanical relay operated by a multi-vibrator. A simplified wiring diagram for flight testing is shown in Fig. 7. A typical flight test signal consists of a signal proportional to stress, the calibrating signal, and, superimposed upon these, unidirectional pulses which are triggered from the aircraft generator once in every four revolutions. The pilot is provided with a manual switch for changeover between any of three gauges and ordinary speech with the ground. The order of vibration may be determined with precision by counting the number of vibrations between two engine-timing pulses, i.e., four engine revolutions.

Air cooling is required for the mercury slip-rings; on the test bed it is supplied from the works' mains but during the ground run on the aerodrome it is supplied from a mobile compressor. In flight it is provided by ram air; the heat generated during the take-off run is not sufficient to cause trouble.

It is not practicable for the pilot to adjust the engine speed with sufficient precision to ensure that stress measurements may be taken at a speed corresponding to a resonance of bucket vibration, particularly in the case of the extremely sharply-tuned nozzle guide-vane orders. The technique is, therefore, to accelerate the engine gradually through the speed range and to make the records upon magnetic tape on the ground. The engine speed is determined accurately by ensuring that the tape is running through the recorder at a known speed during recording and playback. The capstan motor in the recorder is driven from an electrically-operated tuning fork with an electronic amplifier. The tuning fork is, in turn, checked against a quartz-crystal-controlled oscillator which is standardised against a transmission of the British Broadcasting Corporation.

Messrs. Muirhead and Company, Limited, have developed, in conjunction with Pametrada, an electronic wave analyser, of the feed-back type, that greatly reduces the labour involved in analysing the record. It can be switched to pass-band widths of 10 or 3 per cent., or to the "in-tune" position. A tape may be played back into the recorder set to the wide band, and the approximate frequency determined. During subsequent "replays" the frequency of the analyser may be re-set to the exact frequency, with the switch first in the narrow-band position and later in the "in-tune" position. Once the analyser has been set for frequency, the amplitude of a steady signal may be read with great accuracy straight from the meter provided. Unfortunately, such a simple system is not applicable to bursts of stress, the duration of which are small compared with the periodic time of the instrument needle. In this case the output of the analyser, which is in effect a filter, is fed to a cathode-ray oscillograph which, in conjunction with a slow continuous-paper camera, provides a record of any bursts of stress at any selected frequency during a complete engine acceleration from idling to governed speed. The paper record shows the calibrating signal as well as the signal proportional to stress.

Stress measurements early in 1949, on Rolls-Royce Derwent engines, showed that the turbine buckets vibrated in many modes, as shown in Fig. 8, opposite; though it seemed probable that the excitation was aerodynamic, the exact mechanism was not clear and it was difficult to see how to reduce these aerodynamic forces. It was realised that any bucket in a disc would act as a harmonic stabiliser for any other bucket, provided that the two buckets were not excited in step. Clearly, two adjacent buckets are not excited in step by any one wake. In order to investigate the practicability of damping in this manner, a number of buckets were welded into a scrap disc, and it was established that when one bucket was bowed the energy transferred from it to the next, or to a bucket considerably separated from it, was very great, provided that the buckets were tuned to the same frequency.

Strain gauges were then attached to the disc in a running engine and it was determined that the disc was being stressed at frequencies corresponding to the known resonant frequencies of the buckets in the majority of modes. It was established, therefore, that energy was passing from the buckets into the disc. In April, 1950, an engine was run in which 15 buckets were tuned as accurately as possible to the same frequency in the first torsional mode. The stresses in the first torsional mode in the 15 tuned and adjacent buckets were found to be just under one-quarter of the stresses normally measured. It is not possible, however, to tune buckets to the same frequency in every mode and it was necessary, therefore, to determine with certainty the mode or modes that were responsible for the failures that had been occurring in service. A peculiar symptom of the trouble with the Derwent 5 turbine buckets was that, although the incidence of failure under service conditions of flight was serious, failure on the test-bed was almost unknown despite many strenuous attempts to repeat flight conditions. It was for this reason that during the summer of 1950 Rolls-Royce undertook flight testing; immediately it became apparent that the nozzle guide-vane order stresses increased in flight, especially at high speed and low altitude, by a factor of about 3 to 1, whereas the lower-order stresses were virtually unaltered. The reason for this behaviour, however, is still unknown.

LONDON ASSOCIATION OF ENGINEERS.—The London Association of Engineers celebrates the centenary of its formation in 1952 and will mark the occasion by a centenary festival on May 2, at the Connaught Rooms, Great Queen-street, London, W.C.2.

SOME UNKNOWNS IN GEAR DESIGN.*

By DR. H. E. MERRITT, M.B.E.

(Concluded from page 735.)

As is well known, rating formulæ for surface loading (commonly called "wear" formulæ) are intended to cover two kinds of surface failure quite different in character. One is pitting, which is a failure of the material below the surface, and the other is failure of the oil film, with results variously described as scuffing, scoring, galling, picking-up, ridging, and so on. Even pitting, the simpler of these two broad types of failure, is not yet properly understood. In some experiments, cracks have been discovered below the surface, but it would perhaps be an over-simplification to suppose that these cracks are merely the result of the sub-surface shear stresses, as calculated by static Hertzian methods. Evidence that the phenomena are much more complex is provided, firstly by the occasional occurrence of pitting over the flank profile of both of a pair of gears, both face-profiles remaining smooth. Meldahl, in experiments on rolling-sliding discs, showed that pitting tended first to occur on the discs having a negative slide-roll ratio; but that pitting was also influenced by the type of lubricant. It therefore seems clear that pitting is a much more complex affair than static-stress calculations would suggest. The hypothesis that pits are propagated by oil trapped in a crack sealed under pressure is incomplete, and we need to know why the crack reaches the surface. Two possible influences are, firstly, the tangential stress at the surface resulting from tooth friction, and the other is the very high changes of temperature in the surface layers under the band of contact (demonstrated by Professor Blok); these sudden temperature changes could be imagined to produce rapid changes of tensile and compressive stresses on a plane perpendicular to the surface. If this is so, the thermal conductivity of the material is an important factor, and some support is given to this by the fact that the surface loading which bronze worm wheels will carry is much higher than one would expect if one merely took the hardness or tensile strength of the material into account.

The second class of failure, by breakdown of the lubricant, is even more complex, since the properties of an additional material, namely, the lubricant, are involved. A full understanding of the way in which the oil film behaves is still awaited, and in reading the literature one suspects too great a pre-occupation with purely mathematical analysis, and too little experimental work. As usually happens, it is necessary for the engineer to be able to design a piece of machinery, and to have it working, before the scientist can explain to him how it works. Similarly in the case of gears: it may be a long time before the real nature of lubricated line contact is understood, but it is still a necessary practical step to find out how rating formulæ may be modified in order to make a more complete allowance for differences in the sliding-rolling characteristics of different designs of tooth, and for more subtle differences in physical properties of the gear materials.

Even before definite evidence is available which would justify a change in the present basis for determining permissible surface loading, there is room for the further investigation of the basic surface stresses now given in the B.S. gear specifications. It seems improbable that truly comparative basic stresses for different materials would be as smoothly related to ultimate tensile strength as the currently-used values would suggest. A further consideration, which current methods do not take into account, is the influence of the material of the mating gear, whether by reason of its modulus of elasticity, thermal conductivity or the coefficient of friction of the combination; the last-named will also vary with the lubricant.

Lubrication is too large a question to be dealt with in detail in this short paper, particularly having regard to the way in which one question has been complicated by the development of additives. But to add fuel to the flames which discussion of this subject may provoke, the author would observe that, with the exception of the development of E.P. oils for hypoid gears, research on gear lubrication has long been quite inadequate. A great deal of plausible theorising has been done, but there is very little evidence, derived from controlled experiment, to support it. Meanwhile, scuffing continues to occur, and has been particularly serious in marine reduction gearing. The subject is clearly one for co-operative research in which the voice of the B.G.M.A. should be clearly heard. Where do we go from here?

The discussion on Dr. Merritt's paper was opened by Mr. H. G. White (Messrs. Alfred Wiseman and Company, Limited), who said that Dr. Merritt seemed to consider alloy steels necessary in case-hardened gears. He himself did not subscribe to that view. If the case thickness were adequate, a straight carbon steel was just as good as an alloy steel. He would grant that when one had to make a gear integral with the shaft, alloy steel was necessary for the shaft stresses; but the crux of the problem was the case thickness rather than the material of which the gear was made. He knew of no gears which were more subject to abuse from the point of view of alignment than traction gears. On a face-width basis, traction gears were not highly loaded, but the mis-alignment which took place in them was what caused service failures. A very thick case had been found essential to the transmission of the powers required from them.

The Association had a glorious opportunity of carrying out investigational work, except that they had no money; at least, as an Association they had no money. He estimated that the gear industry in this country spent about 10,000*l.* a year in sending people to British Standards Institution meetings to deliberate on gear design, but most of the benefit did not accrue to the gear industry itself. It was of more benefit to people outside the industry. If that 10,000*l.*—and more—were spent on investigations such as those outlined in the paper, it would be spent to better effect. It did not necessarily mean setting up a research establishment. There were plenty of places up and down the country—in the universities, for instance. If one could put the problem to these various organisations, provide the gears and testing machines for them and tell them what was wanted, they could probably supply the answers to a number of the points raised in Dr. Merritt's paper.

Mr. E. B. Wilson (E.N.V. Engineering Company, Limited) questioned whether the potential value of the savings which could be effected was so great as was indicated by Dr. Merritt. Most gears existed to transmit power from a prime mover to wheels or propellers or some means of absorbing the power. In most cases, the gears were designed for the original outputs of the prime mover, and during the course of the development of the prime mover the power probably increased by 20, 30, 40 or even 50 per cent. During that period, the gears underwent rigorous testing in service, which was one of the best means of proving them, and they underwent development with the prime mover. In other words, there would only be a large potential saving on the assumption that most gear units were very much too large for the powers which they transmitted. He did not believe that this was the case to-day. It might be worse economy to design units more skimpily and then have to scrap them when the powers that they had to transmit in any particular set-up were increased. The results achieved by research were disappointing. It did not seem to have yielded a very rich harvest, and he did not know quite why that was. It was possibly because it was very expensive, and probably one of the reasons why it was expensive was that there was a very wide scatter in the results obtained—even on any one particular sample. This added greatly to the cost of testing. In fact, a pre-requisite of testing might be research into the methods of testing in order to reduce, if possible, the wide scatter in the results. Dr. Merritt had referred to the old "chestnut" of pounds per inch of face-width, and had said that a last effort was needed. It was certainly a very unscientific means of assessing gear loads, but it still served a practical purpose in comparing like with like. It was a very easy way, when comparing two similar gear applications, of drawing comparisons between the two. One could, of course, go wrong on it, but one could at least arrive at a result in a very short space of time and use it to see, in the more elaborate calculations which were necessary, that some considerable error had not been made. Dr. Merritt had also referred to case-hardened gears. This was extremely important, and no doubt more and more gears would be made from case-hardened steels. It was extraordinary that one controlled the quality of the steels very accurately, but when they went through the carburising process one got the widest variety of structures and composition in the case. Metallurgists had a great job to do in drawing up accurate specifications for heat treatment that did in fact control the quality of case-hardened gears.

Mr. C. Timms (Mechanical Engineering Research Laboratory) said that he supported wholeheartedly the plea for fundamental research on gearing. Work was in progress at both the A.V.G.R.A. and P.A.M.E.T.R.A.D.A. on improvement in the accuracy and full-scale testing of marine gears, but in the automobile and aero-engine field there was a need for a more combined effort on the subject as a whole. The number of gears required for investigation purposes was relatively small, and it was difficult to meet experimental requirements from commercial sources of supply especially when firms were concerned with long production runs. This meant that a laboratory must have its own gear-cutting facilities for hobbing, shaving and

* Paper presented at an extraordinary general meeting of the British Gear Manufacturers Association, held in the Piccadilly Hotel, London, W.1, on November 6, 1951.

grinding gears under controlled conditions. Another important requirement was the supply of adequate precision measuring equipment so that the effect of variations in tooth spacing, profile, alignment and surface finish could be investigated on gear test units designed to simulate normal conditions of service.

In the Mechanical Engineering Research Laboratory at East Kilbride, it was the policy to carry out a comprehensive research programme on the intermediate sizes of gear drives, and in this connection adequate facilities for manufacture, inspection and testing of gear units were in hand. It was considered that the "scatter of results" referred to would be greatly reduced if all the tools were available in one organisation. Dr. Merritt had not referred in his paper to gear metrology, though he had mentioned gear errors. It was unfortunate but nevertheless true that the amount of gear-measuring equipment made in this country was extremely small, and the same could be said of equipment for the inspection of cutting tools. There was ample scope for firms to interest themselves in the manufacture of precision gear-measuring machines of all types—not only for gears in the automobile range but also in the instrument and marine field. At the moment it was necessary to go abroad for the major part of this equipment, since no firm in this country was making the complete range of precision measuring machines as supplied, for example, by such firms as the Maag Gear-Wheel Company, Zurich, and Société Genevoise, Geneva.

Mr. R. M. Macarthur (The Power Plant Company, Limited) said that Dr. Merritt had referred in several places in his paper to the way in which the B.G.M.A. could contribute to the well-being of the industry. As he understood it, the precise reason for its formation was that more interest might be taken in research. Previous speakers had also referred to the matter, and he heartily endorsed their remarks.

Mr. H. L. Trafford (Messrs. Richard Sizer, Limited) referred to Dr. Merritt's statement that the calculation of horse-power ratings on the basis of so much load per inch of face width had "gone by the board." He asked if Dr. Merritt could explain why, if that were the case, the B.S. formulæ for which Dr. Merritt was larg ly responsible used a pound per inch face rating for determining horse-power.

Rear-Admiral F. T. Mason, Deputy Engineer-in-Chief of the Fleet, said that he agreed wholeheartedly with Mr. Timms. If this country was to survive, it would be because of the excellence of its products. It must make things that people were prepared to buy. It had very strong competitors in the Swiss and the Americans. The question had been asked whether it was a good idea to reduce the size of gearing. As far as naval ships were concerned, it was imperative that the loading rates should go up far beyond what was customary at present. In fact, the Admiralty were busily engaged in spending money on pushing them up. There was an establishment, such as Mr. Timms had described, at Barrow-in-Furness, called the Admiralty Vickers Gearing Research Association, but it dealt with rather large gears. Perhaps Mr. Timms had small ones in mind. There was also the Admiralty Gunnery Establishment, where much work was done on small gears. He asked Dr. Merritt to give his views about the future of ground gears. The Admiralty—possibly in their ignorance—were rather attracted to them. When great accuracy was needed in other things, one turned to grinding, and at the moment—with the higher loading—gears were ground. He knew the disadvantages; hardening, and so on, were troublesome matters. However, grinding would seem to have a future. Switzerland was a neutral country in a hard-currency area and we could be deprived of this source with little or no warning. It was not right that one should have to go to Maag for ground gears. It ought to be possible to produce them here. He was now talking not about the gears produced with Maag machines but about gears produced in England with British machines. If this could be done, it would put us in the forefront of gear manufacture, particularly as it appeared that the Americans were wedded to hobbed and shaved gears. The Admiralty actually had the design of a grinding head and they were concerned to get it developed. There was no use in developing it, however, if the experts did not think there was anything in grinding. Not being an expert himself, he would say that there was something in it. Gear cases must certainly come down so far as the Navy was concerned. Ships had to carry more and more armament and ammunition, and the space occupied by the machinery must be reduced.

The chairman, Mr. A. Sykes (Messrs. David Brown and Sons (Huddersfield), Limited), said that before asking Dr. Merritt to reply, he would like to make one or two comments himself. Dr. Merritt had referred to many factors about which there was uncertainty. The problem was complicated because the same factors of load and speed could produce different results in the way of scuffing, breakage, ridging, etc. It was often very difficult to distinguish one cause from another. It was, however, very encouraging to see that there was a tendency towards co-operation. The Association was in itself a mark of that. Dr. Merritt had referred to allowance for deflection which was usually provided for in rear-axle drives, and had intimated that something ought to be done in other directions. He might be interested to know that a movement was being made on these lines. For example, attention was being devoted to traction gears, to which Mr. White had referred. There was need to make provision for this kind of relief in a more systematic manner, however. Turbine gears had also been mentioned, and the need for correcting helices. Something was being done here with a view to modifying helices to allow for torsional and transverse deflection. Dr. Merritt said that it was surprising some gears ran at all when one thought of the difficult conditions they had to stand up to and the stresses imposed by unknown deflections. Perhaps there were mitigating factors which were sometimes overlooked. For example, the deflection of wheel rims could compensate, to some extent, for the deflection of pinions, and even gear-cases were not entirely rigid. They could give to some extent to the load and help to distribute it. The author had said truly that a closed door was as useful in keeping information out as in keeping it in. He himself had heard of firms who had nursed a secret for a long time, only to find that it was not only known but was obsolete.

Dr. Merritt said, in reply, that the fact that he was now in a position to look at the problem somewhat objectively was perhaps the result of his experience during the last two years. During that time, he had been impressed by the common failure to analyse problems: that was a pastime requiring a lot of spare time and no particular worries. Given that situation, one could sit back in a chair and really think, which was often more profitable, though more difficult, than pushing on and spending a lot of money without thinking. He would not burden the meeting with figures on the commercial value of discoveries made in more detached scientific surroundings. These could be looked up, and they would be found to be staggering. There was no case at all for believing that money spent on research would not prove to be the best of all possible investments, provided the money was spent intelligently and by the proper people. He was encouraged, therefore, by the support that had come from the meeting for the idea of more research or, as Mr. Timms had said, better co-ordination of the existing research facilities.

In reply to Mr. White, he said that in some circumstances an alloy content was necessary in order to achieve the necessary hardenability of the steel. But he would go halfway towards Mr. White's point and say that he suspected a good deal more alloy was used than was necessary. There was a long tradition in the steel business that with a case-hardened material one must have a very tough core, whereas it had been shown, notably by Almen, that what made a case-hardened tooth strong was the case and not the core. Provided the case was deep enough and there was a reasonable transition from the case to the core, the physical properties of the core were not so important. This was indicated in the B.S. specifications, in which basic bending stresses were by no means related solely to core properties but also reflected the properties of the case.

Mr. Wilson had raised a number of very interesting points. One of them might be bracketed with a previous comment on the use of pounds per inch of face-width as the basis of rating. A possible misunderstanding on that point should be removed. The use of pounds per inch of face-width was indefensible if it implied that two pairs of gears of the same materials would transmit the same load per inch of face-width, regardless of their dimensions. The British Standard formulæ quoted permissible loading in terms of pounds per inch of face-width, but the permissable load was not constant; it was calculated from the dimensions of the gears. On other points raised by Mr. Wilson there could be a glorious argument. The point he himself would emphasise was this: that no one who was going in for research expected some miracle to happen, gear units being suddenly made much smaller. He agreed in this connection that there were many cases in which the gears were known to be only just good enough. What might happen, he thought, after a more detailed study of the research problem, was that stresses and ratings would be by degrees adjusted with a substantial cumulative effect. One might consider the current British Standard specifications: the basic stresses were "rounded off," because there was insufficient information to justify expressing them to the last digit. But if the gear dimensions were selected precisely to accord with the specification, an increase of basic surface stress by one per cent. would reduce the weight of the gears by one per cent.

With regard to scatter in the results of fatigue tests, he agreed that one or two tests were of no value, and could in fact be misleading. That applied to things other than gears. One had to do a large number of tests and analyse them statistically. As an example of what could be done by taking a sufficiently large number, however, he need only refer to some of the publications of Almen on motor-car transmission gears. In reply to Admiral Mason, he said that he would phrase the problem of ground gears differently, and would speak of case-hardened gears rather than ground gears. One would adopt grinding only in order to make a case-hardened gear possible, having regard to the fact that at the present time the distortion of case-hardened gears was such that they could not be produced to the standards of accuracy required of gears for marine propulsion without grinding. But the load-carrying capacity of case-hardened gears was vastly greater than that of any gear material that could be finish-cut, and in order to achieve the smaller dimensions and weight which would accompany the use of case-hardened gears, grinding was essential, and the development of the grinding process was therefore the first step in this potentially tremendous technical advance.

TRADE PUBLICATIONS.

Centrifuges.—Bulletin No. 551, published by Sharples Centrifuges, Ltd., Woodchester, Stroud, Gloucestershire, describes their "Super-Centrifuges" for use in marine service, chemical works, steel mills, engineering works, etc.

Relays, Counters and Timers.—Concise facts regarding the numerous types of relays, electronic counters, timers and other equipment manufactured by them are given in a publication received from Londex Ltd., 207, Anerley-road, London, S.E.20.

Pneumatic Plant for Conveying and Dust Collection.—The Sturtevant Engineering Co., Ltd., Southern House, Cannon-street, London, E.C.4, have sent us a well-illustrated brochure describing pneumatic plant for dust-collecting and for conveying light materials.

Fork-lift Trucks.—Two illustrated leaflets have been issued by Ransomes, Sims & Jefferies, Ltd., Ipswich, giving specifications of their 10-ton and 2-ton electric-hydraulic fork-lift trucks, both of which are equipped with telescopic lifting gear and tilting masts.

Fans.—A leaflet issued by Keith Blackman, Ltd., Mill Mead-road, London, N.17, gives the characteristics, etc., of their 16-in. air-circulating fan which is mounted on a 7-ft. stand and is used for improving local air circulation in workshops, offices, etc. Another leaflet gives details of their "Tornado" "man-cooling" fan for use in hot areas in iron and steel works, etc.

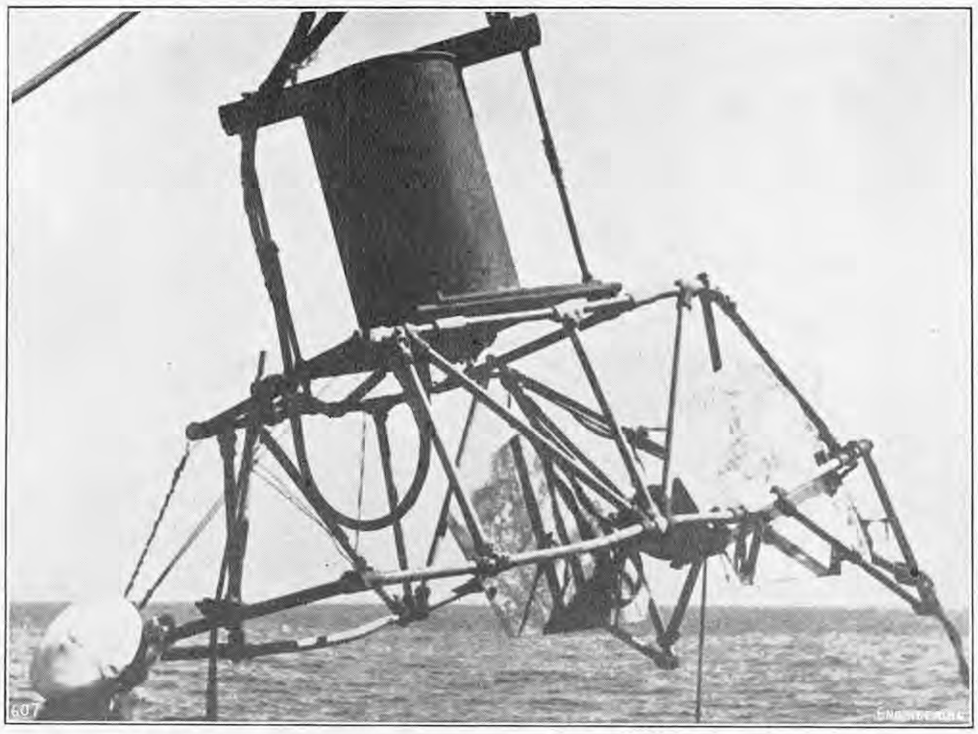
Gear-Generating Machines.—We have received from W. E. Sykes, Ltd., Staines, Middlesex, an illustrated leaflet giving particulars of their vertical gear-generating machine V.10A, for cutting external gears up to a maximum diameter of 14 in., and internal gears with a maximum external diameter of 24 in. and a maximum internal diameter of 6½ in., using automatic infeed or 20 in. without automatic infeed. For generating helical gears, quickly interchangeable cutter-spindle guides are available.

Gear Pumps.—Using their experience in the production of hydraulic pumps for aircraft, the Plessey Co., Ltd., Ilford, Essex, have developed a range of 98 industrial hydraulic pumps, with capacities varying from 0·27 to 42 gallons a minute. A special feature of the design is the use of pressure-loaded bearings which assist in maintaining high volumetric efficiency by limiting the side clearance between the gear and bearing faces to a value sufficient only to maintain a satisfactory oil film between the surfaces. The firm have issued a booklet describing these gear pumps.

Nickel-Iron Alloys.—A wide range of thermal and magnetic properties are useful characteristics of nickel-iron alloys. A booklet published by the Mond Nickel Co., Ltd., Sunderland House, Curzon-street, London, W.1, and entitled "The Physical Properties of the Nickel-Iron Alloys," gives data on the tensile strength, hardness and electrical resistance of the binary alloys and on the elastic and expansion properties of both the binary and the more complex alloys. A section deals with their uses in temperature-control devices, for expansion control in engineering components and for glass-to-metal seals.

Chucks.—Crawford & Co. (Tottenham), Ltd., Tower Hill Works, Witney, Oxfordshire, have issued a brochure on their Trugrip chucks and accessories. The design is based on the collet principle, actuated by means of a key through a pinion and bevel gear. Various forms of collet are provided: a standard collet for bar work; a collet for gripping discs; one for holding rings; etc. The makers stress the value of the chuck for 2nd operation work on centre lathes and grinders. It is made in two sizes, namely, 5 in. and 7 in., with bar capacities of 1 in. and 2 in., respectively; but the ring, disc, etc., capacities are greater.

UNDERWATER TELEVISION.



UNDERWATER TELEVISION IN SEARCH FOR THE "AFFRAY."

It is now possible to give some information regarding the part played by underwater television in identifying the position of H.M. Submarine Affray, which was lost in the English Channel on Monday, April 16, 1951. The equipment used for this purpose was supplied by Marconi's Wireless Telegraph Company, Limited, Chelmsford, and consisted of a portable camera "chain," the principal part of which was an Image Orthicon pick-up tube, manufactured by the English Electric Valve Company, Limited, Kingsway, London, W.C.2. The camera was built into an underwater container by a team of four members of the Royal Naval Scientific Service who worked on it night and day for three weeks and who also designed the remote controls for operating the equipment. The container consisted of a welded-steel cylinder, 17 in. in diameter and 24 in. long, shown in the photograph reproduced on this page. It was designed to work at a maximum depth of 200 ft., although actually a depth of 280 ft. was reached. Considerable bumping was also successfully withstood, in spite of the fact that there was not time to design and prepare shock-absorbing mountings.

The camera and lens window, which was of $\frac{5}{8}$-in. plate glass with a clear aperture of 3 in., was attached to the removable end of the cylinder, as was the cable gland. The single lens used was 2 in. in diameter with an aperture of f 1·9, but was set on infinity at f 4. No electronic modifications were necessary in the camera or tube circuits, but additional instrumentation was incorporated, the spare cable cores (which normally carry communication channels from control positions to the camera operators) being used for this purpose. Illumination was provided by a $1\frac{1}{2}$-kW diver's lamp, which was suitably shielded to prevent direct light from reaching the lens. The lamp was mounted on the tubular framework, visible in the illustration, which provided some protection to the camera. The apparatus was suspended from a derrick on the well deck of the Admiralty diving ship, H.M.S. Reclaim, and proved much simpler to handle than was expected. The camera was moved to the desired position by shifting the whole ship.

Connection from the camera to the wave-form generators, control equipment and monitors, which were installed in the captain's cabin, was made through a 500-ft. multi-core cable, which was handled separately from the camera; and through which the video signals, scan currents, power supply and other necessary electrical requirements were transmitted. The cable was manufactured by British Insulated Callender's Cables, Limited, Norfolk-street, London, W.C.2, and was of the 32-core type, similar to that used for broadcasting purposes. It was, however, provided with additional protective sheathing, so that it could be successfully employed at great depths.

In addition to the normal camera monitor, a main viewing screen was provided by an English Electric receiver, which was adapted to receive signals directly from the line. The extra instrumentation mentioned above included the remote operation of the camera heater and cooling fans, an indicator showing the temperature inside the camera, a remote-level indicator and a leak detector, these being necessary owing to the fact that the correct operation of an Image Orthicon tube depends on the maintenance of a given temperature. The range of the camera was 15 ft. or more, compared with the 5 ft. possible when divers are employed, but the greatest advantage was that the camera could be used continuously under water for two hours, while a diver can only work for a few minutes at the depth required. H.M.S. Reclaim sailed on Sunday, May 27, with the television installation on board and early in June the various parts of the submarine came into view on the screen and the name Affray could be read. Some hours later the divers were able to identify the vessel by normal methods.

ELECTRICITY SUPPLY IN SOUTH UIST.—The Secretary of State for Scotland (the Rt. Hon. James Stuart, M.P.) has confirmed a scheme prepared by the North of Scotland Hydro-Electric Board for the construction of a Diesel generating station at Daliburgh in South Uist.

BRITISH RAILWAYS' OLDEST LOCOMOTIVE.—The oldest working locomotive on the British Railways, No. 58110, has been taken out of service to be broken up at the Derby works (London Midland Region), after a life of 82 years. Originally one of the 315 engines of Matthew Kirtley's "700" class, built at Derby between 1863 and 1874, No. 58110 has borne successively the numbers 778, 2630 and 22630; the present number dates only from the nationalisation of the railways in 1948. The engine is of the 0·6·0 tender type, with cylinders 18 in. bore and 24 in. stroke, and wheels 5 ft. 3 in. in diameter. The heating surface is 1,113 sq. ft., the grate area 17·5 sq. ft., and the working pressure 140 lb. per square inch. The tractive effort was 16,786 lb. and the total weight, with tender, 75 tons $11\frac{1}{4}$ cwt. Latterly, the engine has been employed on freight trains between London and Derby.

AUTOMATIC DOOR SWITCH.—Messrs. Arcolectric (Switches), Limited, Central-avenue, West Molesey, Surrey, have produced a small push switch which is designed primarily to make and break an electrical circuit on the opening and closing of a door. Obvious applications of the switch include the control of a light within a refrigerator, wardrobe, or car; but it may also be used as a limit switch. The switch, catalogued as No. S 930, is rated at 1 ampere at 250 volts, and is designed for fixing in a single $\frac{1}{2}$-in. hole like a panel-mounted toggle-switch. The make and break action is accomplished by means of an insulated plunger which is spring-loaded to maintain the circuit closed. A small depression of the plunger, however, suffices to open the circuit, and the rest of the permitted movement of the plunger—about $\frac{3}{8}$ in.—serves merely to compress the spring farther. All the current-carrying parts of the switch are silver-plated.

TECHNICAL COLLEGES AND EDUCATION FOR THE ELECTRICAL INDUSTRY.*

By H. L. HASLEGRAVE.

BEFORE a young man can be considered a competent electrical engineer, eligible for corporate membership of the Institution of Electrical Engineers, he should have obtained a good general education and a specified minimum of technical knowledge, have had a sound practical training and have held a responsible position for at least two years. Both technical colleges and universities are concerned with the first and third of these requirements. The characteristics required by a man holding a responsible position in industry are exceedingly diverse; and it would therefore seem that there is room for more than one method of developing the potential abilities of youths. A system of training and education is, however, satisfactory only if it provides means for the development of the whole of a youth's facilities as well as for securing the requisite technical knowledge and skill. The conditions prevailing during training must therefore encourage "mixing" in works and at the college or university; and facilities for social, athletic and recreational life should be given almost as much consideration as those for instruction.

The technical institution provides full-time courses, taken before, after, or sandwiched in the period of practical training; and part-time courses (day or evening or a combination of the two) taken concurrently with the practical training. Full-time courses, to be satisfactory, must provide means whereby the students may attain the requisite technical knowledge and also develop their ability to accept responsibility and to direct and control others. As regards instructional facilities the main requirements are lecture rooms and adequately equipped laboratories, a well-qualified and able teaching staff and a well-organised system of tuition, incorporating ample time for tutorial work and private study. Most institutions, however, need increased and modernised equipment, increased laboratory assistance, allowance for more specialisation in teaching; a reduction in the weekly teaching timetable, allowances for private study with or without supervision, and adequate time for corporate and group activities.

The facilities available in a technical college should embrace such a wide range that every student can find something in which he is interested. The material requirements are adequate common rooms, lecture halls, refectories, playing fields and gymnasiums. Hostels are of great value in forming a nucleus for the growth of a strong corporate body; and it would benefit both students and college if they were large enough to allow all full-time students to reside there for at least a year. The contribution which social and athletic activities can make towards the training of students is not sufficiently appreciated by those responsible for technical colleges and a change of attitude is necessary if the development of an engineer is to be complete.

The same reasoning as for full-time courses applies to part-time courses in so far as lecture rooms, laboratories and staff are concerned. There is a limit to the time which the student can spend at college each week, and it is necessary to give in that time such instruction as can be given only by use of laboratory and other equipment and such as is best given by personal contact of teacher and student. There is the same need, as for full-time students, for ample time to read, think and work. But as these students are in direct day-to-day contact with industrial applications they are better able to understand the implications of the principles they learn in the lectures. They are also under less pressure than the full-time student to keep up to date with lectures, which follow so quickly on each other. On the other hand, the part-time student is subjected to greater physical and mental strain and has to exercise considerable self-discipline in order to devote adequate time to social and athletic activities and to private study. Hence his timetable can include very little, if any, allowance for tutorial work and he must be stimulated to study in his own time by the incentive of home work.

The second point is that, as the weekly time available for laboratory work is comparatively small, there have been tendencies to leave the necessary recording of this work and even much of the actual work itself to the end of the session; and hence to prevent the suitable correlation of theory with practice and to impair the value of the laboratory instruction. Much more attention to the planning of curricula is therefore necessary. The corporate activities of a technical institution must allow fully for the needs of part-time students.

There are arguments both for and against technical institutions being used for degree courses. The author

* Paper read before the Institution of Electrical Engineers on Thursday, December 6, 1951. Abridged.

suggests, however, that neither full-time nor part-time engineering degree courses should be provided (with certain exceptions), but that some of the colleges should organise a different type of course. One of industry's needs appears to be for engineers possessing a sound knowledge of the fundamentals of science; who have undergone a specialist training in the applications of these fundamentals to engineering; who can take a broad view of industry and its needs; and who are flexible and adaptable in mind and action. These men must have powers of analysis, precision of thought, judgment and power to make their judgment effective. They must be "productivity-minded" and capable of translating ideas into material things made in an economical fashion.

The technical training necessary to develop this type of engineer should be biased towards practical applications; and should include a large measure of actually doing things and seeing production carried out. The right mental outlook must be secured by making the student tend, from the early days of his training, to translate ideas into action, to make decisions and to act upon them. To achieve this aim the closest possible linking of academic work with industrial training is necessary, as well as careful and original planning of both technical and practical training. A sandwich course is that for which technical colleges are best suited. As the course must include a good training in basic scientific principles, mathematics, physics and chemistry should be dealt with early. Drawing, principles of electricity, mechanics and theory of mechanics, hydraulics, heat engines, materials and structures, which are fundamental to all branches of engineering, must be included. Workshop technology and manufacturing technique should be treated so as to cover many of the technological applications of the other subjects. The syllabuses would have to be compiled specially for this course, which should be treated as basic; provision being made for the post-graduate courses, which would be attended at later stages. The help of executives in industry, who will employ those undergoing the course, should be sought in compiling the syllabuses. A different outlook of industry towards education is thus called for. This includes a willingness to allow engineers carrying heavy responsibilities to return to study for short periods, and intimate participation in the decision of what is to be taught in the basic course.

The entry age should be a minimum of 17 years, with a specified minimum standard of general and technical education. Transfer from National Certificate courses to this particular course should be possible at appropriate stages. The examination papers should be set by the staff of each technical college and there should be an external assessor for the final papers. This would avoid the cumbersome National Certificate procedure, while maintaining a national minimum standard. Students should also be required to undertake some practical project; either after the final written examination or during the last six months of the course. This project should aim at testing the student's ability to apply knowledge gained during the course, to obtain relevant knowledge from other sources, to analyse data, select critical factors and to make decisions. His attainments in this project should be assessed therefore more upon the way in which it had been carried out than upon the final result. During the last third of the course, students should be given small projects involving the correlation of knowledge gained at college with actual works cases. A course of this type would be suitable for the award of the Associateship of the new College of Technologists, but its value should be judged by its contribution to industry's requirements. About 300 of the engineers annually passing through these courses are likely to be absorbed by industry. For these, 12 or 15 colleges would be necessary.

Investigation and research can be taken as coming within the general category of post-graduate courses, but in the past the attitudes of various technical colleges to these matters have been very mixed. The chief obstacle has been finance. The research work should be undertaken in colleges which are situated in an area where industry has particular needs. If industry were able to make suitable contributions towards expenditure, assistants could be appointed solely for research purposes. Research projects can be used for training students in method. While research must take place to ensure "live" teaching, care must be taken not to give it undue weight, to ensure that only suitable staff are given facilities, and that research is not undertaken solely to secure higher degrees for staff and students.

The present provision of part-time day and evening courses for craftsmen is not good enough in many colleges and even when it is there is generally a tendency to finish at the stage of the final examination of the City and Guilds of London Institute. There is, therefore, a need for advanced courses, which technical colleges should provide. The term "craftsman" covers a wide variety of occupations, so that the individual's particular needs will have to be met by means of either a one-night-per-week course, a short full-time intensive course or a conference type of course involving attendance, say, all day Friday and on Saturday morning. It would help considerably to ensure that the status of the craftsman is recognised at its full value if a national certification were created. It is suggested that three grades of certificates should be granted, the awards being based on a practical test to be taken by all apprentices at the end of the basic training period and a series of written examinations of the intermediate and final grades conducted by the City and Guilds of London Institute.

Attention has recently been drawn to the need for preparing training and education schemes for technicians, and it has been stressed that very little suitable educational provision is made for them at present. The reasons for this lack are that it is not clearly understood by staffs of technical colleges what technicians really are; that Ordinary and Higher National Certificate courses appear to have satisfied demands in the past; that industry has been almost silent about what it really requires; and that in many areas the numbers of students do not justify organising the separate types of courses that would be necessary. One of the main difficulties is the wide range of occupations and types of technicians. Their mental and manual abilities also vary very much. Consequently, no single course can be expected to be suitable.

The author suggests a two-year course for technicians engaged in the manufacturing industry. This would follow the Ordinary National Certificate course and lead to an award of a "Higher National Certificate in Electrical Technology." It should preferably be of the one day per week type and should be followed by endorsement courses requiring attendance on one evening a week in subjects particularly relating to the work of the technician in manufacture. The problem of providing similar courses for technicians on the generation and supply side of industry and in electrical communication is more difficult, since the needs are not as clearly defined and the candidates are more scattered. Courses would be of the one-day per week or of the full-time sandwich type. It is likely that there would be a greater need for the second type than in the case of technicians employed in manufacturing. These courses would also lead to the award of the "Higher Certificate in Electrical Technology" with the possible addition of "(Supply)." Endorsement courses in specialist items would be necessary. If the courses are to be successful there must be a good understanding of the needs of the different types of technicians; and the courses must be carefully designed in accordance with these needs, with syllabuses compiled from advice obtained from persons of long and responsible experience in industry. Colleges will have to adopt somewhat unorthodox tuition and organisation. This branch of work of technical institution is most important and justifies the devotion of a great deal of attention.

CATALOGUE LIBRARY IN GLASGOW.—The Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2, has opened a catalogue library which contains literature issued by more than 3,000 firms, as well as a complete set of British Standards. Frequent additions are made by the firms represented, and supervision of the material by a technical staff ensures that it is kept up to date. Manufacturers are invited to include the Centre on their mailing lists.

TWIN-ENGINE DELTA-WING AIRCRAFT.

THE GLOSTER AIRCRAFT COMPANY, LIMITED, HUCCLECOTE.

NEW TWIN-ENGINE DELTA-WING FIGHTER AIRCRAFT.

THE first British delta-wing aircraft designed as an operational long-range day and night fighter, the GA5, constructed by the Gloster Aircraft Company, Limited, Hucclecote, Gloucestershire, flew for the first time on Monday, November 26, at Moreton Valance aerodrome, Gloucestershire. It may be recalled that former delta-wing aircraft—the Avro 707A and 707B, the Boulton Paul P.111, and the Fairey FD1—were all designed for research purposes and are all small single-engine machines. The Gloster GA 5, however, which is shown in the accompanying illustration, is a powerful aircraft driven by two Armstrong Siddeley Sapphire axial-flow jet engines, with a static sea-level thrust officially exceeding 7,000 lb. each. No details of the performance, armament or radar equipment have been published.

SHIPS' GRAVITY DAVITS.—Messrs. J. Stone and Company (Charlton), Ltd., Woolwich-road, Charlton, S.E.7, have announced that they have concluded an agreement with the Marepa Trust, Ltd., Liverpool, whereby they acquire an exclusive licence for the sale and manufacture of Marepa-type gravity davits for ships' lifeboats. These davits, which will be manufactured and sold under the name of Stone-Marepa, will be supplied with either electric or hand-operated winches and fitted with grooved drums, centrifugal brakes and deadweight-operated ratchet hand brakes. The design is fully approved by the Ministry of Transport and complies with the latest requirements for the saving of life at sea.

EVENING CLASSES IN LONDON.—The Principal of the Sir John Cass College, Jewry-street, Aldgate, London, E.C.3, announces a series of evening courses to be delivered in the college, commencing in January, 1952. In all cases, lectures are at weekly intervals, begin at 6 p.m., and last one hour or more. Fees range from 15s. to 30s. and the numbers of lectures from five to ten. The courses and their commencing dates are as follows. X-ray crystallography (January 10), absorption spectroscopy (January 11), radiation detectors and counters (January 15), microchemical analysis (January 15), patents and industrial design protection (January 24), distillation (January 25). Applications for enrolment forms should be made to the Principal prior to the opening dates. A prospectus containing full particulars may also be obtained on application to the college.

TROPICAL AND HIGH-ALTITUDE TRIALS OF VISCOUNT 700 AIR LINER.—The prototype Viscount 700 air liner, constructed by Messrs. Vickers-Armstrongs Limited, Weybridge, Surrey, has recently completed extensive tropical and high-altitude flight trials in Africa; the aircraft returned to England on Friday, November 30. During take-offs from Khartoum and the high-altitude airfields at Nairobi and Entebbe, the water/methanol injection system, with which the Viscount's four Rolls-Royce Dart propeller turbines are equipped, was used very successfully. Routine maintenance only was required on the engines and the aircraft during the trials. It may be recalled that Viscount 700 air liners have been ordered by British European Airways, and are described by them as the "Discovery" class; the first deliveries are expected in the autumn of 1952, and they should be in service early in 1953. Twelve Viscounts have also been ordered by Air France and four by Aer Lingus.

PUMP FOR CORROSIVE AND VISCOUS LIQUIDS.

AMES CROSTA MILLS AND COMPANY, LIMITED, HEYWOOD.

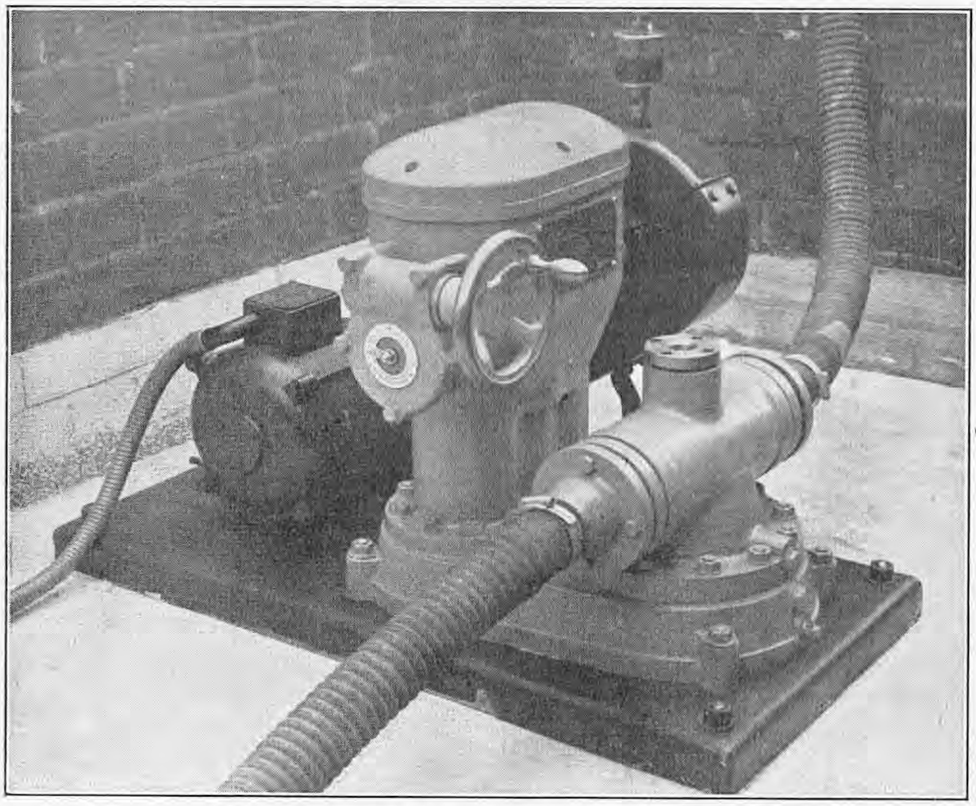
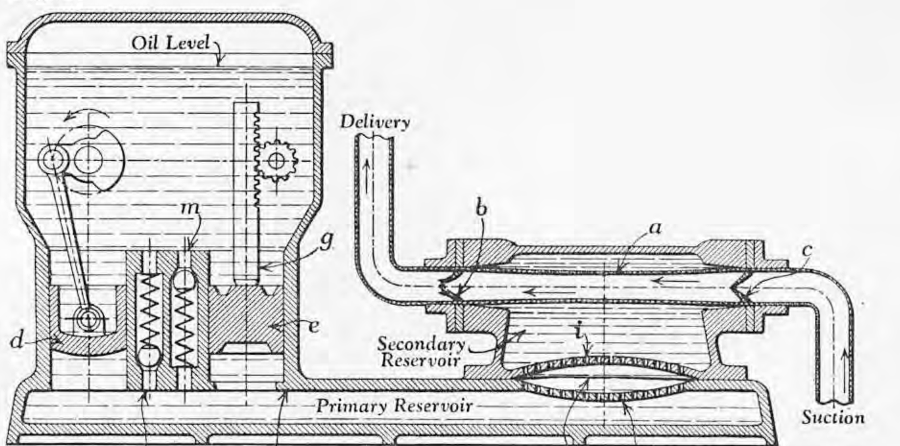


FIG. 1. MANUALLY-REGULATED "SIMPULSIC" PUMP.

Fig. 2.



VARIABLE-CAPACITY PUMP FOR CORROSIVE AND VISCOUS LIQUIDS.

IN many industries and processes, corrosive, viscous or other liquids which are difficult to handle have to be pumped at controlled rates. A simple and easily-serviced pump has been developed recently for this purpose, in which the rate of delivery can be regulated from zero to maximum flow, either manually or automatically, while the pump is running. The Simpulsic pump, as it is styled, is designed and constructed by Messrs. Ames Crosta Mills and Company, Limited, Heywood, Lancashire. The pump is illustrated in Fig. 1, and a simplified sectional diagram is reproduced in Fig. 2. The liquid is conveyed in a flexible-rubber duct, completely separated from the mechanical elements of the pump and from any metal parts, and is forced through the duct by pulsations generated in the tube by the pumping mechanism. The pulsating action effectively prevents any tendency for the liquid to encrust and choke the pipes.

Referring to Fig. 2, it will be seen that the flexible-rubber tube *a* is immersed in oil. The pumping mechanism imparts alternate pressure and suction impulses through the oil, causing the tube to contract and expand alternately. The tube is provided with rubber non-return valves *b* and *c* at the inlet and outlet of the pumping section; when the tube is compressed, valve *b* opens and valve *c* is closed, so that the liquid is expelled through the delivery outlet. On the alternate impulse, as the tube expands valve *b* closes and valve *c* opens, drawing in liquid from the suction inlet. The rate of flow through the pipe depends upon the frequency and amplitude of the pressure impulses, which are produced by the power-driven piston *d*, which has a fixed stroke, and the floating piston *e* which is free to travel between a fixed stop *f* and an adjustable stop *g*. If the latter is set so that the stroke of the floating piston is the same as that of the driven piston, no pressure impulses are produced; by progressively lowering the adjustable stop and reducing the stroke of the floating piston, the impulses produced by the reciprocating piston *d* increase until a maximum value is reached when the floating piston is held solidly against the fixed stop.

The oil transmitting the pressure impulses is contained in two reservoirs, separated by a diaphragm *h* which has a range of movement restricted by two perforated limiting discs *i* and *k*. The secondary reservoir in which the flexible tube is housed is completely sealed, so that the oil contained in it cannot escape; this is an essential feature of the pump, preventing the setting up of unequal stress distribution in the tube walls, which might arise if oil leakage could take place. In the primary reservoir, i.e., the space between the pistons and the diaphragm, provision is made for compensating for any oil leakage past the pistons by means of the two spring-loaded ball valves *l* and *m*, the valve *l* allowing for the return of any excess oil in the primary reservoir, whereas any loss of oil in the primary reservoir is compensated by the valve *m* which opens under suction to allow oil to flow in. It will be seen that the lubrication of all the working parts is ensured by enclosing them completely in the reserve oil above the piston.

The stroke of the floating piston may either be controlled manually, through a worm and worm gear, as in Fig. 1, or it can be connected to a servo-mechanism for automatic control. An example of the type of application for which the Simpulsic pump is particularly suited is the neutralisation of an acid effluent by the addition of lime slurry, the output of the pump being automatically regulated by a *p*H-recorder/controller responding to the acidity and rate of flow of the effluent.

STRUCTURAL PROBLEMS OF ADVANCED AIRCRAFT.

THAT the rapid development of the high-speed high-altitude aircraft has greatly complicated the structural designer's task was demonstrated in a review of some of the "Structural Problems of Advanced Aircraft," given in a paper by Mr. H. H. Gardner, F.R.Ae.S., to the Royal Aeronautical Society on November 29. Between the wars, said Mr. Gardner, it was notable that a structural requirement for tapered wings of high thickness-chord ratio led, rather than followed, aerodynamic design; stressed-skin construction was generally adopted, but no optimum structural solution emerged. The approach to a shell structure had begun. It was general practice to make use of previously successful detail design.

Towards the end of the Second World War, the Brabazon Committee of the Ministry of Aircraft Production produced specifications for future civil aircraft. With one exception, the immediate post-war civil aircraft operated at moderate speeds (up to 300 knots), and altitudes (up to 25,000 ft.); the principal problems were those of pressurised structures, transparencies and dielectrics, and the life of aircraft structures, all of which still remained to be solved satisfactorily; strength and stiffness problems had not yet become acute. New specifications for military aircraft increased the need for structural efficiency. The low structure weight necessary to enable the aircraft to reach the altitudes specified had become more difficult to achieve with the reduced thickness/chord ratio of the wings, and the need to bury the engines in the wings. On a military aircraft of about 100,000 lb. all-up weight, a 2 per cent. saving in structure weight would give an overall saving in take-off weight of 6 per cent. or more.

Since the end of the Second World War, aluminium-copper alloys for structures had been progressively superseded by the newer aluminium-zinc-magnesium alloys of higher strength. Buried engines, requiring access doors and large holes in the leading and trailing edges of the main structural box, had led to the retention of heavy spar booms, of considerable size to allow for the machining from the solid of mating parts for the spar joints, a more economical method of jointing than the use of steel couplings. Difficulties had arisen, in sections of about 6 in. thick in aluminium-zinc-magnesium alloy, from distortion after machining, and a variation of strength across the section resulting in a 6 to 7 per cent. lower core strength. With highly-tapered spar booms, to avoid distortion it was advisable to machine in the solution-treated condition in order that any correction might be made before precipitation. In the case of forgings, it was necessary to rough-machine in the annealed condition before fully heat-treating, and to allow a 30-hour rest period before machining to size. Another serious disadvantage of the new alloys was the difference in strength along and across the grain, accentuated by stress concentrations.

Ambient temperatures of − 75 deg. to − 90 deg. C. were expected at 50,000 feet. It was thought that mild steels and many stainless steels would not be suitable. There was need for further information on the effect of low temperature on the notch fatigue strength of metals. The most important of the new materials was titanium; in the jet-engine field its ability to withstand high temperatures, its corrosion resistance, and its weldability and low specific weight made it attractive. As a structural material, pure titanium and titanium alloys had strengths comparable with that of high-tensile steel, and strength-to-weight ratios ranging from 1·4 times to more than twice as great. The modulus of elasticity ranged from 6,250 tons to 8,040 tons per square inch.

Structural problems associated with the pressure cabin were introduced principally by departures from the cylindrical or spherical shape, openings for doors and windows, etc. It had been demonstrated mathematically and confirmed experimentally that, in a cabin of circular cross-section, by designing an elliptical opening to certain dimensions, the boundary member was relieved of the bending stresses which would be present in the case of a circular opening. For this reason, the doors and windows of the Viscount air liner were elliptical. A mathematical approach was also applied to designing the front-end bulkhead of a military aircraft, which was required to be concave instead of the usual convex hemisphere. To keep the weight to a minimum, it was built up from arms, loaded in compression only, radiating from a central hub. The plating, subjected to tension only, was formed to the shape which would be taken up by an elastic diaphragm supported on representative edge members and subjected to pressure. The method had also been used successfully for producing catenary-like pressure-floor panels resting on the floor beams, resulting in weight saving and avoiding large deflections. Up to the present, little testing had been carried out on complete cabins, but repeated-load tests on pressure cabins would form part of the structural-test programme on new aircraft. The pressurised fuel tank also required consideration. Low-volatility fuels required a differential pressure of 3 lb. per square inch at 50,000 ft. to suppress boiling. Since a suction of 3 lb. per square inch on the upper wing surface might also be present, a wing fuel-tank structure would have to withstand pressures of about 6 lb. per square inch. If fuels with higher vapour pressures were adopted, the problem would become more acute.

Failures of Perspex fighter canopies could be attributed mainly to the combined effect of differential expansion and notch sensitivity. Solvent glazing could occur at room temperature at stresses above 500 lb. per square inch, and for this reason stringent official requirements for testing Perspex canopies had been laid down. It was believed that a comprehensive strain-gauging technique could be developed which would reduce the considerable amount of testing required. Glass weighed twice as much as Perspex, but would withstand abrasion and was not affected by solvents. It would not withstand a high degree of tension, and, owing to its high modulus of elasticity, it required care in mounting to avoid crack formation. Semi-toughened and toughened glass, which had surface-compressive stresses introduced during cooling, were usually laminated with a vinyl interlayer, which provided a means for flexibly mounting the windscreen by a metal strip, secured to the projecting interlayer only, through which the attachment bolts were fixed. Even so, panels frequently cracked or became delaminated at the edges. Both Perspex and glass were unsatisfactory structural materials.

Possible fatigue failures of civil aircraft had to be considered as the utilisation rates achieved by the airline operators were increasing. Already, there were aircraft still in service with flying lives exceeding 40,000 hours. The majority of failures in operational flying were of a secondary nature, but there had been some catastrophic failures; laboratory fatigue tests appeared to give pessimistic results. An important finding by the Royal Aircraft Establishment was that the endurance of a test joint could be increased considerably, by as much as four times, by using an interference fit, e.g., a taper pin in place of a parallel pin fitted to normal standards. It was known that the life of components could be improved by understressing and by a single application of load of 50 to 70 per cent. of the ultimate design load. It might be, therefore, that the fatigue characteristics of a pressure cabin would be improved by the routine pressure test, and that a flight load of the order of $2g$ would have beneficial effects on a new aeroplane. The development of the counting accelerometer and counting strain gauge had provided suitable means for collecting extensive flight measurements of the load sequences occurring in flight.

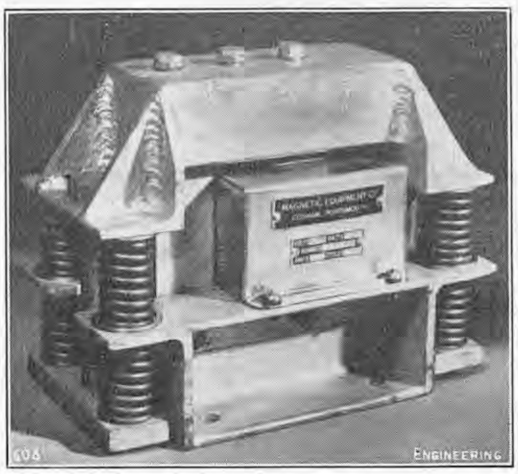
The adoption of swept-back thin wings had increased the magnitude and complexity of aero-elastic effects and transient stresses. In the past, recommended stiffness criteria were sufficient to ensure freedom from flutter, control reversal, and wing divergence. To-day, it was necessary to employ specialist staff to analyse fully in the early design stages the aero-elastic behaviour of the aircraft. In wing design, flutter was the major problem; the establishment of the normal modes of vibration could be expedited with flutter models and with electronic calculating aids, but it was essential to check the calculated modes by a full-scale resonance test before the first flight of the prototype aircraft. Recent investigations at the Royal Aircraft Establishment had suggested that, for a given value of torsional stiffness of the wing, a reduction of flexural stiffness would increase the flutter speed. In order to avoid aileron reversal on swept-back wings, however, a high flexural stiffness was required; if adequate rolling power was to be provided, an appreciable increase of stiffness above the present requirements was required.

On swept-back wings, longitudinal stability could be affected by structural distortion; the loss of incidence at the wing tips due to upward bending led to a forward movement of the aerodynamic centre, and nose-up pitching, resulting in a greater increase of lift. It might be possible to design a wing in which the loss of incidence due to bending would be compensated by an increased incidence due to the rotation of a local region of low torsional stiffness about a local highly-swept-back axis, introduced at about one-quarter of the span outboard.

In conclusion, said Mr. Gardner, more extensive structural research was needed, in particular, to discover a more satisfactory high-tensile light alloy, to expedite the production of titanium, to produce a transparent material without the disadvantages of Perspex and glass, to carry out more endurance testing and to develop large fatigue-testing machines, to adopt generally statistical instruments for recording flight loads on civil aircraft, to find alternative methods for avoiding aero-elastic troubles, and to develop the use of thick sheet and integral stiffeners.

ELECTROMAGNETIC BIN VIBRATOR.

THE accompanying illustration shows one of the electro-magnetic bin vibrators made in three sizes by the Magnetic Equipment Company, Limited, Lake Works, Wicor, Portchester, Hampshire. These vibrators consist of top and bottom units. The latter comprises a laminated magnet system which carries the operating coil. This coil is wound on an insulated metal bobbin and is contained in a metal enclosing cover. The top unit consists of a laminated armature



which is attached to the vibrator body. As will be seen, the two units are connected by springs and the whole system is tuned so that, under working conditions, it is in resonance with the supply frequency. The result is that a powerful vibrating force is obtained with a small power consumption. The units are arranged to operate on single-phase current and the degree of vibration is controlled by varying the amplitude of the armature movement.

The smallest size of vibrator is intended for use with packing machines having a hopper volume of about 7 cub. ft. The next larger size is suitable for hopper volumes up to 50 cub. ft., and the third is intended for still larger applications. It is claimed that the use of this equipment prevents the material arching or clogging up and facilitates the flow even of difficult materials. No lubrication or other attention is required.

GAS TURBINE SCHOOL.—The School of Gas Turbine Technology has just completed its first year in its new premises at Farnborough, Hampshire. During the year, 311 students passed through the school, which provided 17 courses, including two arranged specially for students from overseas. Six courses have already been arranged for 1952, namely, two on industrial gas-turbine technology, two on aero-engine design, a practical course on aero-engines, and an "international" course for overseas students covering both aero and industrial gas turbines.

FABRICATED WATER-TURBINE RUNNER FOR NEW ZEALAND.—In order to reduce the wear caused by the abnormally high silt and sand content of the water, a runner for a 36,000-h.p. turbine in the Highbank station on the Rakaia river, near Christchurch, New Zealand, has been constructed by a new method. The sealing rings have been made of special erosion-resistant stainless steel and only the crown and skirt rings have been cast, the stainless-steel vanes being pre-machined and jig-assembled to ensure the maximum accuracy in the water passages. All the welding was carried out on a manipulator, with a specially developed sequence, in the Rugby works of the contractors—the English Electric Company, Limited. The runner weighs 6½ tons and is 8 ft. in diameter.

BOOKS RECEIVED.

Overseas Economic Surveys. El Salvador. By R. H. TOTTENHAM SMITH. [Price 1s. 6d. net.] *Nicaragua.* By N. O. W. STEWARD. [Price 1s. 3d. net.] H.M. Stationery Office, Kingsway, London, W.C.2.

Films for Industry. Federation of British Industries, 21, Tothill-street, London, S.W.1. [Price 1s. 8d.]

Can Science Stop It Raining? By DR. J. GORDON COOK. Merrow Publishing Company, Limited, 23, Ganghill, Guildford, Surrey. [Price 2s. net.]

Steels in Modern Industry. By W. E. BENBOW. Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 42s. net, postage 11d.]

Deep Diving and Submarine Operations. By SIR ROBERT H. DAVIS. Parts I and II. Fifth edition. The Saint Catherine Press, Limited, 39, Parker-street, London, W.C.2. [Price 35s. net.]

National Physical Laboratory. Test Pamphlet (Schedule of Fees) No. 9. *Tests and Measurements of Gears, Gear Cutting Tools, Gear Hobbing Machines, and Spline and Serration Gauges.* The Director, National Physical Laboratory, Teddington, Middlesex.

Fire Protection and Accident Prevention Year Book 1952. Compiled by GEOFFREY F. D. PRATT. Benn Brothers, Limited, Bouverie House, 154, Fleet-street, London, E.C.4. [Price 10s. 6d., post free.]

Fractional H.P. Electric Motors. By F. H. SPREADBURY. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 35s. net.]

Sound Insulation and Room Acoustics. By PROFESSOR PER V. BRÜEL. Translated by J. M. BORUP. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 35s. net.]

CONTRACTS.

THE HUNSLET ENGINE CO., LTD., Leeds, 10, are in course of delivering six 65-ton 0-6-2 steam tank locomotives, of 5 ft. 6 in. gauge, to the Commissioners of the Port of Calcutta. The locomotives have cylinders 16 in. bore by 24 in. stroke, the wheels are 3 ft. 10 in. in diameter, the boiler pressure 210 lb. per square inch, the adhesion weight 49 tons 5 cwt., and the maximum tractive effort 23,850 lb. The engines are intended to haul 1,200-ton goods trains round curves of 300 ft. radius. The present constitutes the third order for six locomotives placed by the Commissioners with the Hunslet Company.

During November, the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines amounting, in the aggregate, to 13,149,708*l*. These include: main and auxiliary power cables, control cables and accessories for East Yelland power station, near Barnstaple, with ABERDARE CABLES, LTD.; foundations of buildings, circulating water system, cable tunnels and coal stores for Portishead "B" power station, near Bristol, with CHAS. BRAND & SON, LTD.; two 340,000 lb. per hour boilers for Brimsdown power station, with JOHN THOMPSON WATER TUBE BOILERS, LTD.; preliminary civil-engineering work for Castle Donington power station, near Derby, with WM. MOSS & SONS, LTD.; main and auxiliary cables and accessories for Drakelow power station, with BRITISH INSULATED CALLENDER'S CABLES, LTD.; two 300,000 lb. per hour boilers for Bold power station, St. Helens, with YARROW & CO., LTD.; two 300,000 lb. per hour boilers and coal-handling plant for Connah's Quay power station, near Flint, with INTERNATIONAL COMBUSTION, LTD.; foundations and culverts for Ince power station, near Ellesmere Port, with HOLLAND AND HANNEN & CUBITTS, LTD.; three 350,000 lb. per hour boilers for Clarence Dock power station, Liverpool, with BABCOCK & WILCOX, LTD.; four 180,000 lb. per hour boilers for Doncaster power station, with MITCHELL ENGINEERING, LTD.; 132 kV, 2,500-MVA switchgear for Skelton Grange power station, Leeds, with the BRITISH THOMSON-HOUSTON CO., LTD.; two 180,000 lb. per hour boilers for Huddersfield power station with BENNIS COMBUSTION, LTD.; main foundations for Stella South power station, near Newcastle-upon-Tyne, with SIR ROBERT MCALPINE & SONS (NEWCASTLE-UPON-TYNE), LTD., and 132-kV overhead line for this station, with W. T. HENLEY'S TELEGRAPH WORKS CO., LTD.; 11·8-kV lower-voltage cables for Carrington power station, near Manchester, BRITISH INSULATED CALLENDER'S CABLES, LTD.; two 360,000 lb. per hour boilers for Chadderton power station, Oldham, with SIMON-CARVES, LTD.; railway sidings for Fleetwood power station, with THOS. W. WARD, LTD.; one 300,000 lb. per hour boiler for Braehead power station, Renfrew, with BABCOCK AND WILCOX, LTD.; two 120-MVA 275-132-kV auto-transformers for Slough, with the GENERAL ELECTRIC CO., LTD.; 30 MVA 132-33-kV transformers and earthing transformers for Nelson substation, Lancashire, with the YORKSHIRE ELECTRIC TRANSFORMER CO., LTD.; and the 132-kV Devonside to Redhouse overhead transmission line, S.E. Scotland, with RILEY AND NEATE, LTD.