STEELWORK FOR ROAD BRIDGE OVER T

DORMAN, LONG AND C

Fig. 1

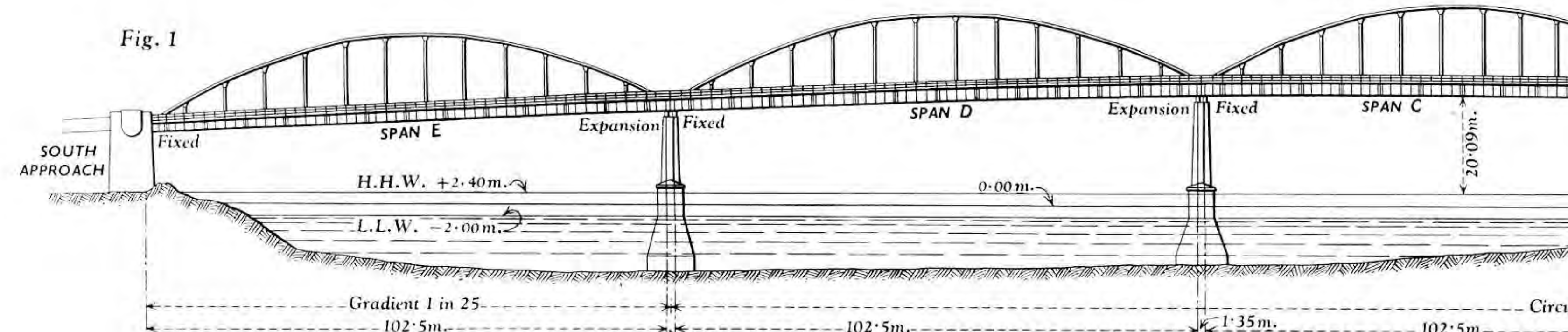


Fig. 3.

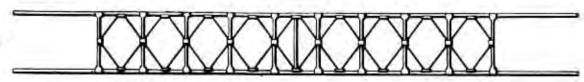


Fig. 2 HALF PLAN OF DECK.

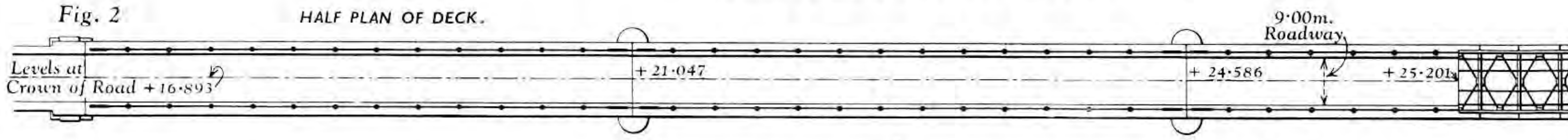


Fig. 5. TOP LATERAL SYSTEM.

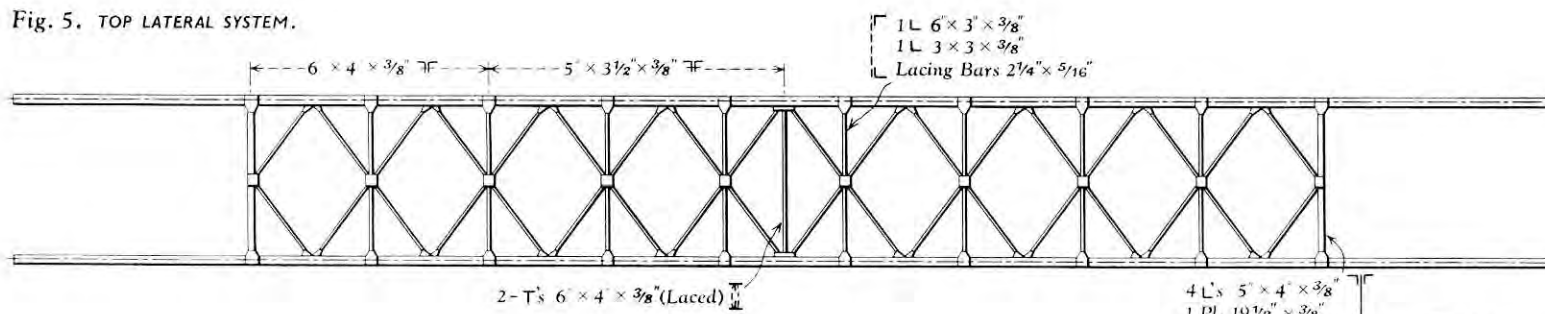


Fig. 9.
FOOTWAY AT IN

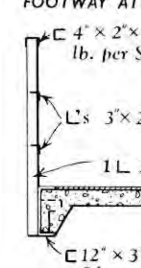
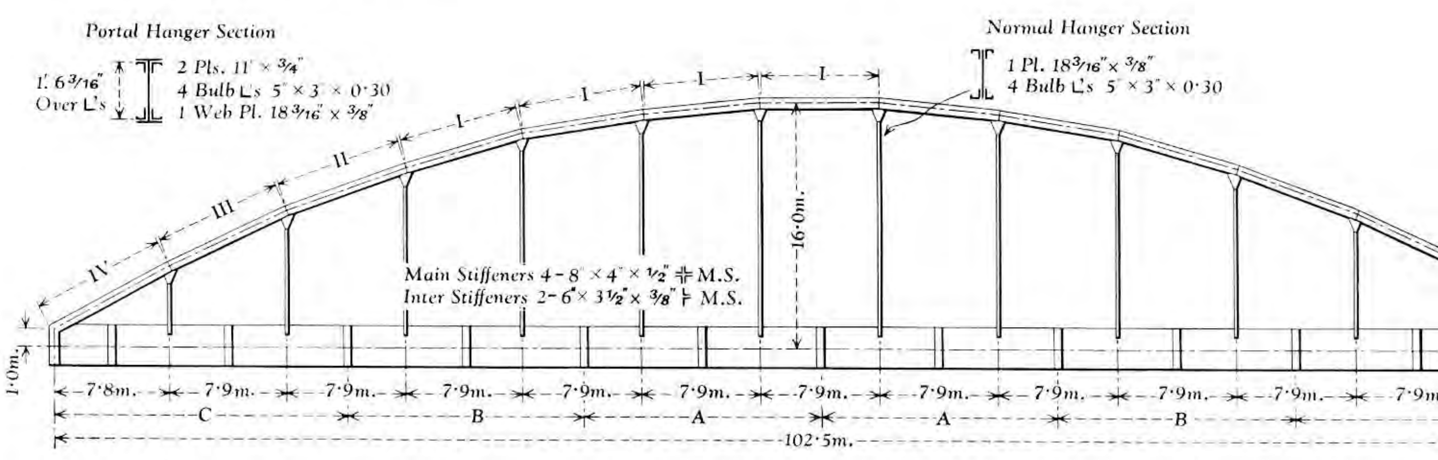


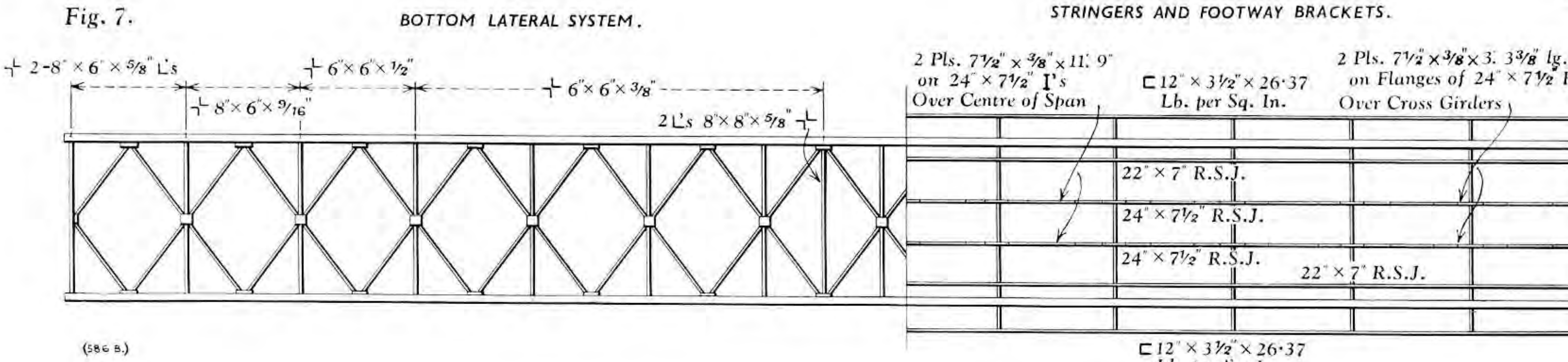
Fig. 6. ELEVATION OF RIVER SPAN.



Hangers and Parapet Standards Vertical. Stiffening Girder Splices, Stiffeners and Cross Girder Connections are Normal to Cambered Sections of Stiffening Girders.

Fig. 7. BOTTOM LATERAL SYSTEM.

STRINGERS AND FOOTWAY BRACKETS.

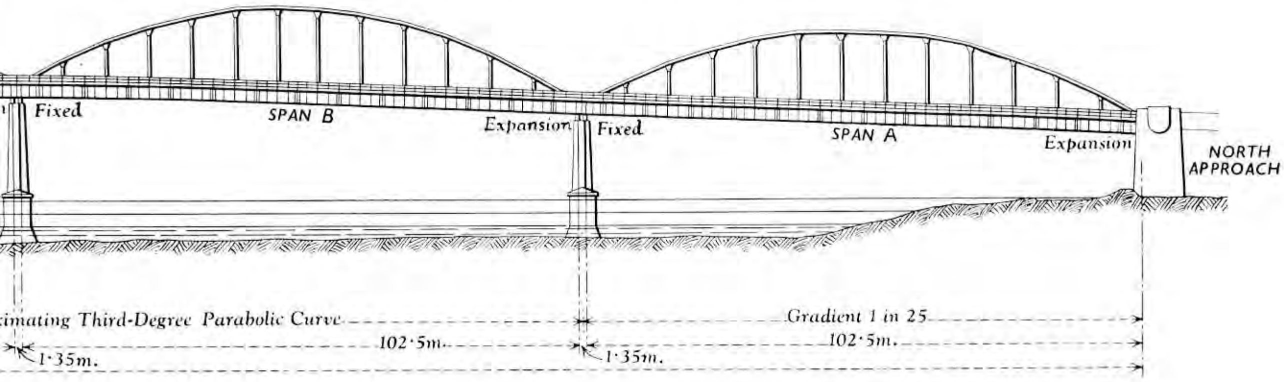


(To go betw

...IVER TAGUS AT VILA FRANCA DE XIRA.

...LIMITED, MIDDLESBROUGH.

(*For Description, see Page* 801.)



HALF PLAN OF DECK STEELWORK.

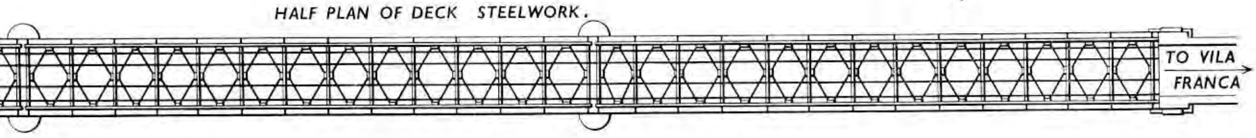
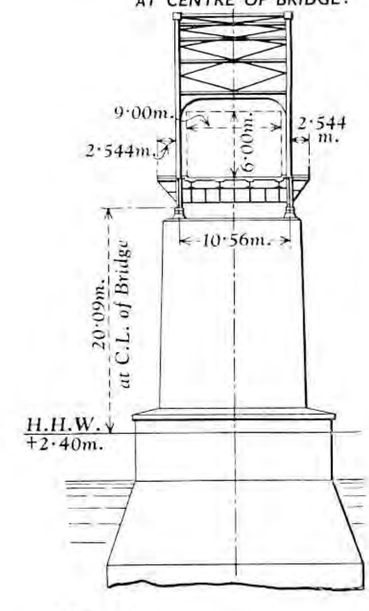
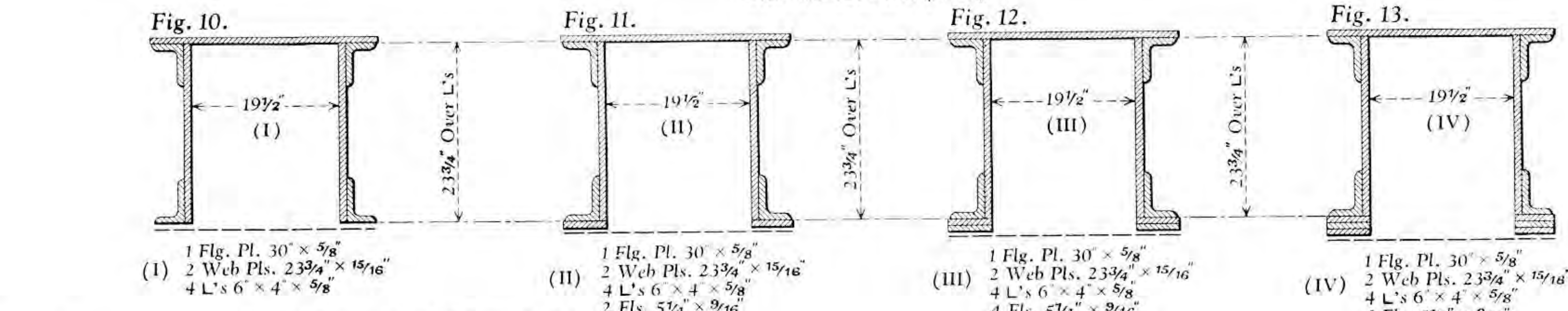


Fig. 4. CROSS SECTION AT CENTRE OF BRIDGE.



ARCH RIB SECTIONS (H.T.S.)

Fig. 10. Fig. 11. Fig. 12. Fig. 13.



POINTS.

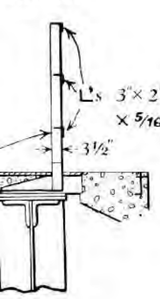


Fig. 14. PART ELEVATION OF PORTAL FRAME.

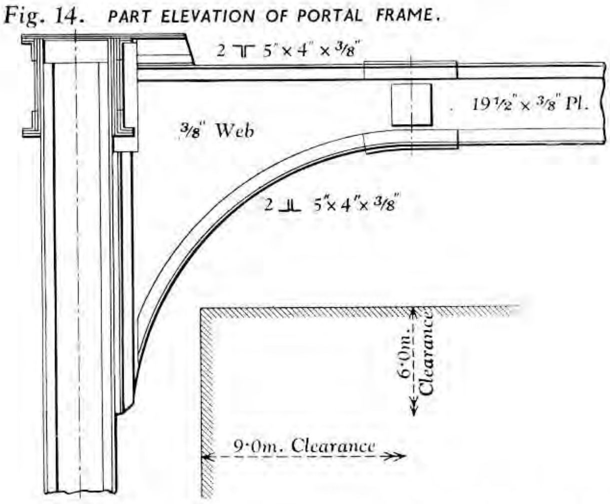


Fig. 15. ORDINARY HANGER CONNECTION.

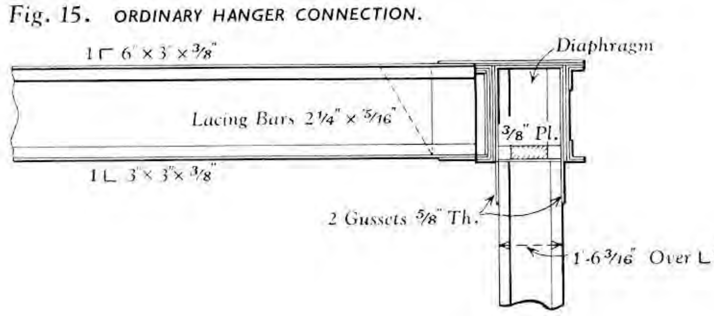


Fig. 16. STIFFENING GIRDER (H.T.S.)

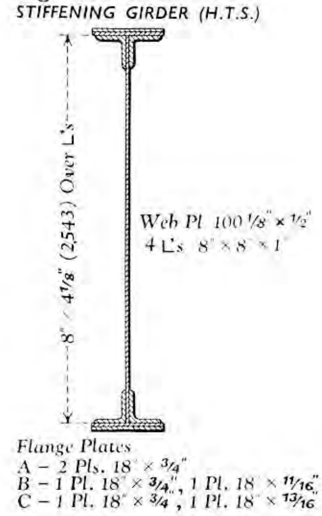
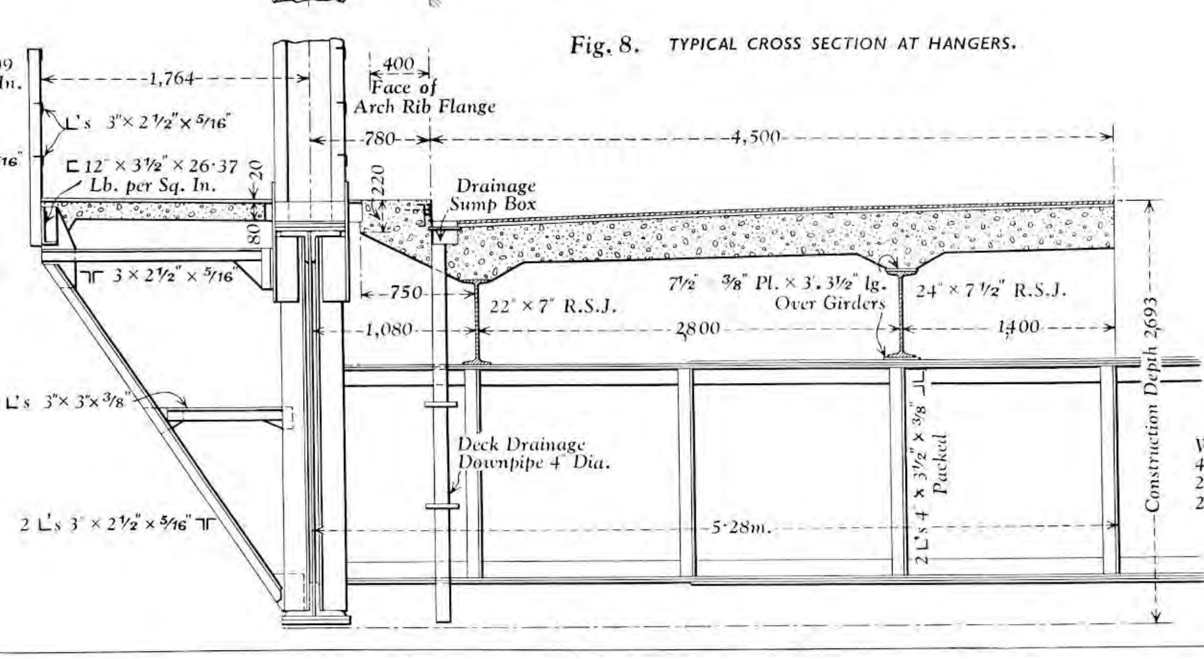


Fig. 8. TYPICAL CROSS SECTION AT HANGERS.



ROAD BRIDGE OVER THE RIVER TAGUS.

AN important link in the road communications between Lisbon and the south and east of Portugal will be completed by the opening, on Sunday next, the 30th instant, of a new bridge over the River Tagus at Vila Franca de Xira, which is situated 20 km. (12½ miles) upstream from Lisbon. Before the completion of this bridge, the river was crossed at Vila Franca de Xira by a ferry, the nearest road bridge being situated at Santarem, 80 km. (50 miles) from Lisbon. The need for improvement in the cross-river communications near Lisbon has been felt for some years and several schemes for bridging the Tagus have been considered from time to time but have been abandoned owing to the width of the river and the difficult foundation conditions near the capital. The nearest point to Lisbon at which the river is sufficiently narrow and the foundation conditions are good enough to render the construction of a bridge reasonably economical is Vila Franca de Xira and, in 1947, the Portuguese Government invited tenders for the construction of a highway bridge at this point.

The Government's proposal, through the National Road Board, was for a suspension bridge with a central span of 850 ft., but tenderers were invited to submit their own alternative designs. Tenders were received from the leading constructional engineering firms on the Continent, the United States, and Great Britain, one of which was Messrs. Dorman, Long and Company, Limited, of Middlesbrough. In view of the strong nationalist sentiment in Portugal, however, Messrs. Dorman, Long's tender was made in association with a Lisbon firm, the Sociedade de Empreitadas e Trabalhos Hidraulicos (Seth), who themselves worked in collaboration with two Danish contractors, Højgaard and Schultz A/S and Kampmann, Kierulff and Saxild A/S, both of Copenhagen. Messrs. Dorman, Long undertook to supply and erect the steel superstructure of the bridge and the Portuguese firm were responsible for the construction of the approaches, piers and foundations, and the road-construction work.

In addition to the suspension bridge design called for in the Government specification, Dorman, Long and Seth prepared alternative designs for two other types of structure, both of which employed five 102·5 m. (336 ft.) spans in the river crossing. In the first alternative design, which was the one adopted, the five spans consist of tied arches stiffened by plate girders located below the deck. In the other design, the river spans were latticed bowstring trusses of welded construction. A suspension bridge following the official design would have been too costly and, at the end of April, 1948, the National Road Board placed the contract with Dorman, Long and Seth on the basis of the first alternative design, the value of the contract being 120 million escudos, or about 1,250,000*l*.

The main dimensions and general arrangement of the bridge are shown in Figs. 1 to 4, on Plate XLIX., Fig. 1 being an elevation, Fig. 2 showing half plans of the deck and the deck steelwork, Fig. 3 showing the top lateral tracing of one of the spans, and Fig. 4 being a cross-section at the centre of the bridge. The total length of the river crossing is 517·9 m. (1,700 ft.) measured between the centres of the abutment bearings, and the overall length of the bridge, including the approach spans, is 1,224 m. (4,015 ft.). It is thus the largest bridge in Portugal and is among the major bridges on the Continent of Europe. The roadway, which is designed for heavy highway traffic, is 9 m. (29 ft. 6 in.) wide and there are footways of 1·5 m. (5 ft.) clear width on each side of the roadway. Fig. 8 is a typical cross-section of the road and footway near one of the hangers which support the roadway from the arch rib, giving particulars of the steelwork of the stringers, cross griders and footway brackets; and Fig. 9 is a section of the footway at an intermediate point. The approaches on each side of the bridge consist of earth-filled embankments followed by reinforced-concrete viaducts formed of continuous beams arranged in groups, each of three bays with spans 20 m. (65 ft. 7 in.), 25 m. (82 ft.) and 20 m. (65 ft. 7 in.) in length. The foundations for the approach piers are carried on precast reinforced-concrete piles up to 35 m. (114 ft. 10 in.) in length. The length of the approach viaduct is 460 m. (1,500 ft.) on the northern, or Vila Franca, side, that on the southern side being 240 m. (790 ft.) in length.

The average width of the river at the site of the bridge is 500 m. (1,640 ft.), and the bed is composed of soft silt of varying consistency for depths up to 30 m. (98 ft.) below water level. Below the silt is a layer of sand and gravel which provides a reasonably good foundation. In forming the foundations for the river piers, the silt was first dredged out to a suitable depth and replaced by sand filling. Hollow reinforced-concrete piles, 66 cm. (26 in.) in diameter and up to 27 m. (88 ft. 6 in.) in length, each capable of supporting a load of 120 tons, were then driven to a bearing in the sand and gravel layer below the silt. The upper ends of the piles were left projecting above the sand filling on the river bed and a reinforced-concrete caisson was then floated out and sunk over them by admitting water into the hollow body of the pier. The water was next forced out by air pressure and the space between the tops of the piles and the bottom of the caisson was filled in solid with concrete. The upper parts of the caisson were then filled in and the pier was built up to its full height. The sketches reproduced in Figs. 17 to 20, on this page, show the various stages of the work, and Fig. 21 shows a section of a completed pier with the steel superstructure in position. The caissons, it may be explained, were constructed in and launched from a floating dock constructed for the purpose by the contractors.

The five arches which form the superstructure of the bridge have a total weight of just over 3,000 tons, about 57 per cent. of which is of high-tensile steel. All the steel was supplied from the Dorman, Long works at Middlesbrough, two of the spans having been fabricated at the Dorman Long Bridge and Constructional Works, Middlesbrough, and three by Messrs. Braithwaite and Company, at West Bromwich. It was shipped to the site and unloaded at the contractors' wharf at Vila Franca, whence it was transferred to the stockyard. The general arrangement of the steelwork is illustrated in Figs. 5, 6 and 7, on Plate XLIX, the elevation, Fig. 6, showing that each span is divided into 13 bays, two of which are 7·8 m. (25 ft. 7 in.) in length and the remainder 7·9 m. (26 ft.). The roadway and footways, sections of which are shown in Figs. 8 and 9, are supported from the arch rib by vertical hangers, sections through two of which are shown in the upper part of Fig. 6. These hangers, although normally in tension, are designed to resist compression as they were required to support the weight of the arch rib during the erection of the span. A portal frame is provided between the second and third bays from each end of the span and details of the connection of the hangers to the arch rib at one of the portal frames and at one of the ordinary frames, respectively, are given in Figs. 14 and 15. Figs. 10 to 13 show the four different sections of which the arch rib is composed, the Roman numeral on the sections and those in Fig. 6 indicating the parts of the rib at which the particular sections are taken. The arch rib and the stiffening girders, a section of one of which is shown in Fig. 16, are constructed of high-tensile steel, to B.S.S. 548, which, as already mentioned, accounts for about 57 per cent. of the total weight of steel in the span. A plan of the lateral bracing at the top of the span is given in Fig. 5, and the left-hand half of Fig. 7 is a part plan of the bottom lateral system; the right-hand half of Fig. 7 is a part plan of the decking, showing the stringers and footway brackets.

The erection of the river spans, each of which weighs about 600 tons, was carried out by Dorman, Long and Co., and forms, probably, the most interesting part of the work. Owing to the soft nature of the river bed and the great depth to firm

CONSTRUCTION OF RIVER PIERS.

Fig. 17.

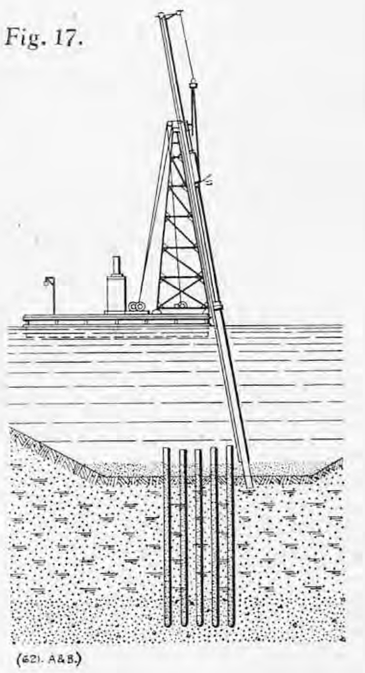


Fig. 18.

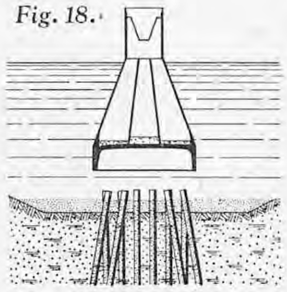


Fig. 19.

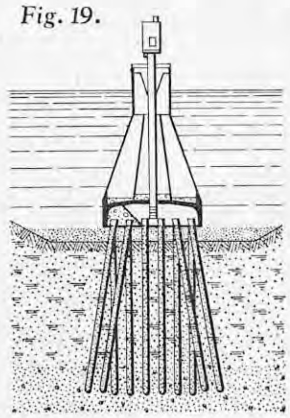


Fig. 20.

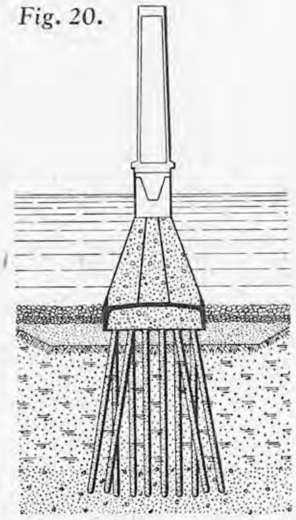
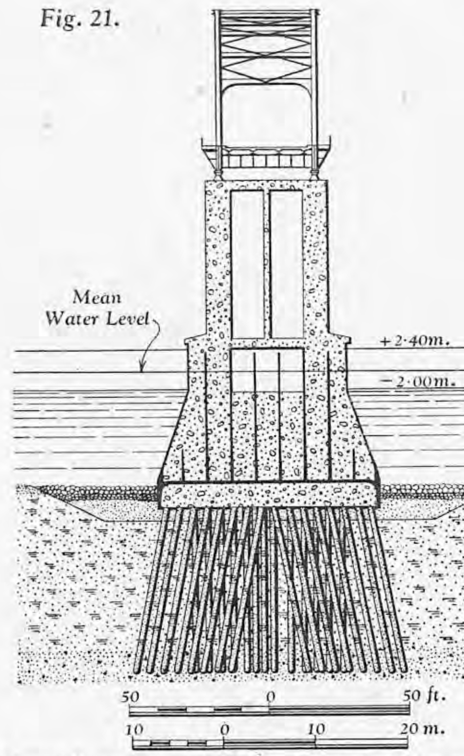


Fig. 21.



ERECTION OF ROAD BRIDGE OVER THE RIVER TAGUS.

DORMAN, LONG AND COMPANY, LIMITED, MIDDLESBROUGH.

Fig. 22.

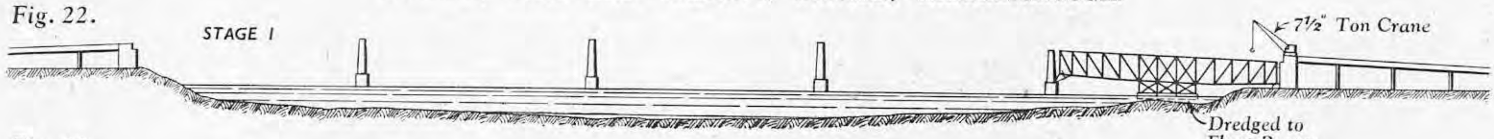


Fig. 23.

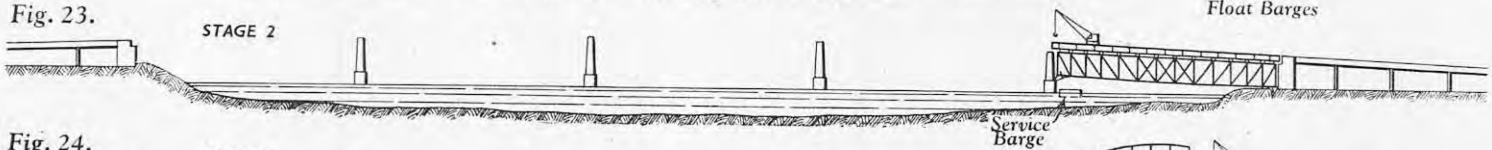


Fig. 24.

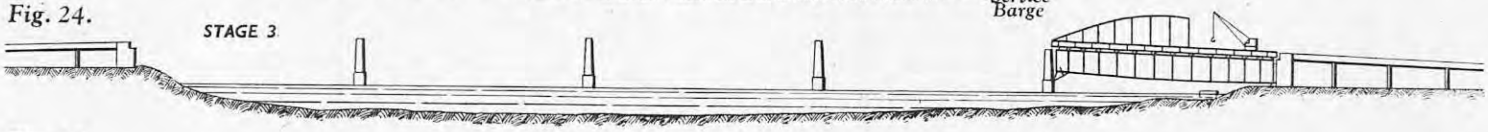


Fig. 25.

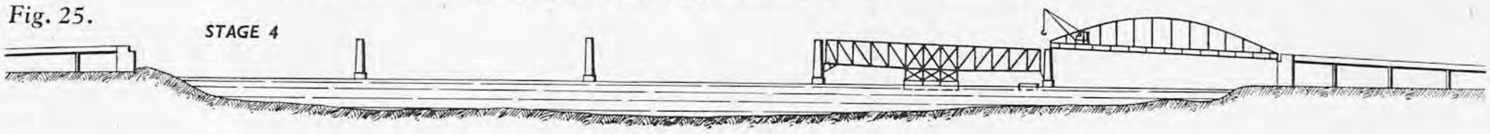


Fig. 26.

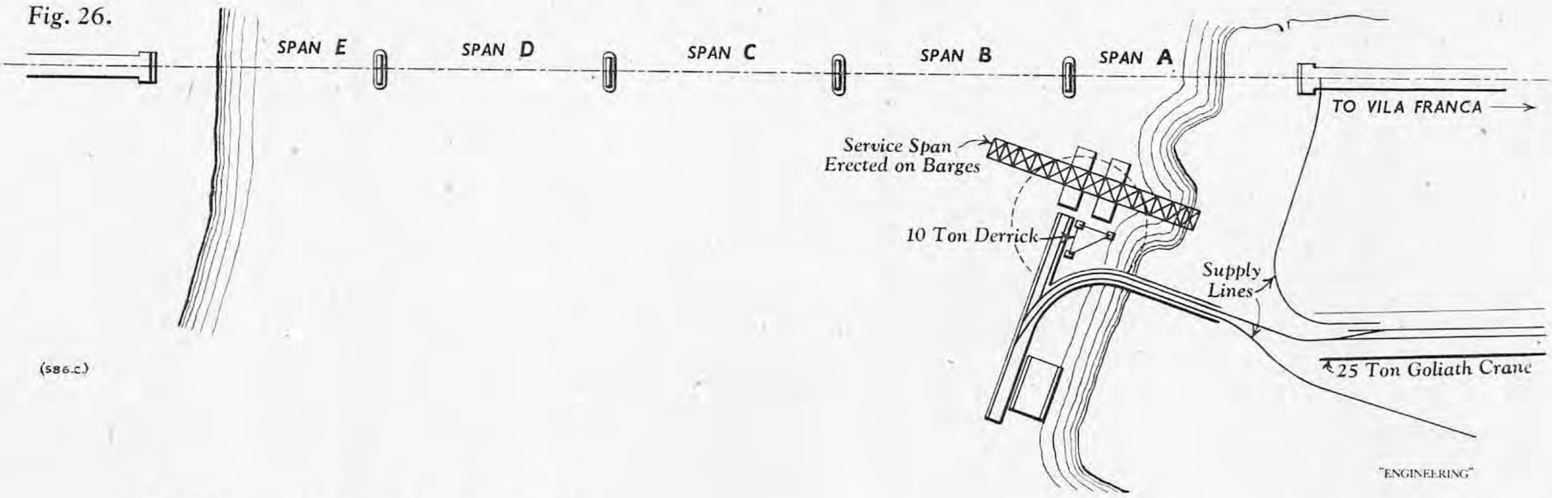


Fig. 27. ELEVATION IN POSITION FOR BAY C.

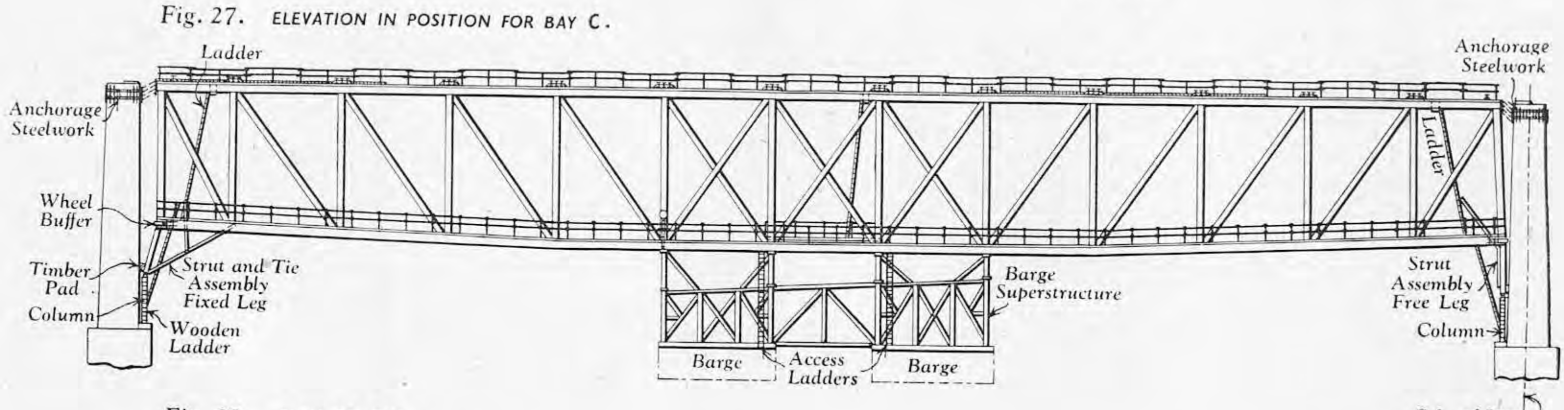
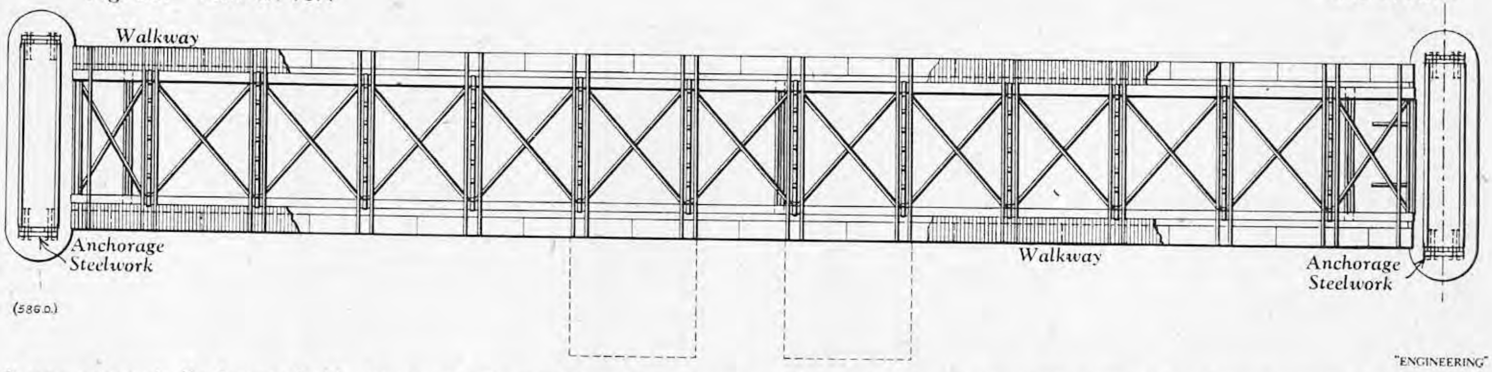


Fig. 28. PLAN ON TOP.



ground, it was economically impracticable to use a normal type of falsework or scaffolding to support the spans during erection; moreover, the design of the spans employed did not lend itself to cantilever erection. It was therefore decided to employ a trussed steel service span as a temporary support for each of the permanent spans during erection. As the erection of one of the permanent spans was completed, the service span was moved into position to support the next, and so on. The service span, mounted on two barges, was floated into the opening between two piers and lowered so that its ends rested on the plinths of the piers. The barges were then removed, packings of suitable height placed on top of the service span, and the permanent steelwork assembled on the packings by means of a $7\frac{1}{2}$-ton locomotive crane. When completed, the permanent span was jacked up at each end from the tops of the piers, the packings removed, and the span lowered on to its permanent bearings on the piers. These bearings, it may be noted, are of cast steel and have a total weight of 60 tons. The fixed bearing for each main girder is provided with a segmental hemispherical rocking seat and the expansion bearing with two rollers 15 in. in diameter.

Operations were commenced from the northern,

ERECTION OF ROAD BRIDGE OVER RIVER TAGUS.

DORMAN, LONG AND COMPANY, LIMITED, MIDDLESBROUGH.

(*For Description, see Page* 801.)

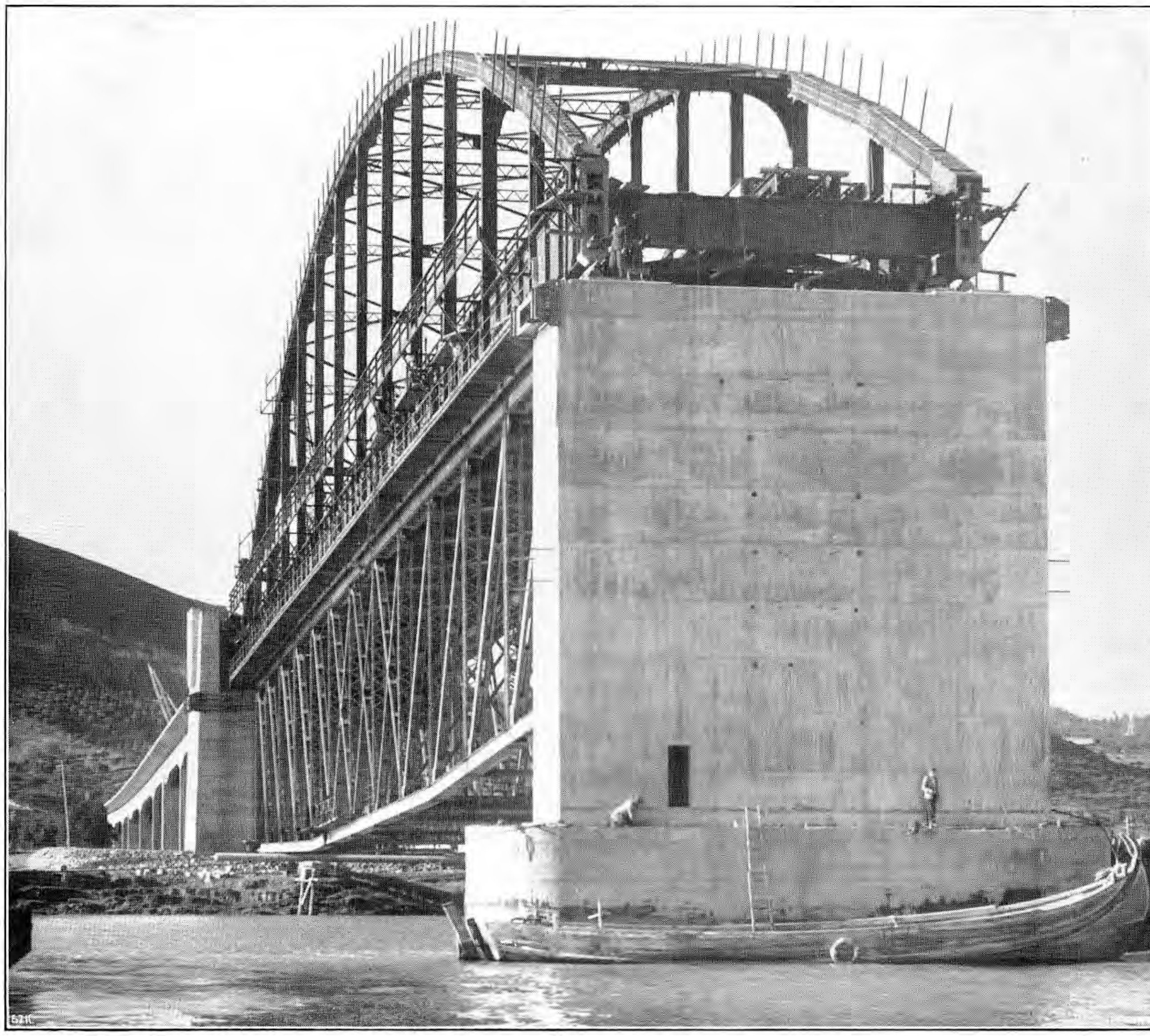


FIG. 29. ERECTION OF SPAN "A" NEARLY COMPLETED, WITH SERVICE SPAN IN POSITION.

FIG. 30. SERVICE SPAN BEING MANŒUVRED INTO POSITION FOR THE ERECTION OF SPAN "B."

(*To face page* 802.)

ERECTION OF ROAD BRIDGE OVER THE RIVER TAGUS AT VILA FRANCA DE XIRA.

DORMAN, LONG AND COMPANY, LIMITED, MIDDLESBROUGH.

(*For Description, see Page* 801.)

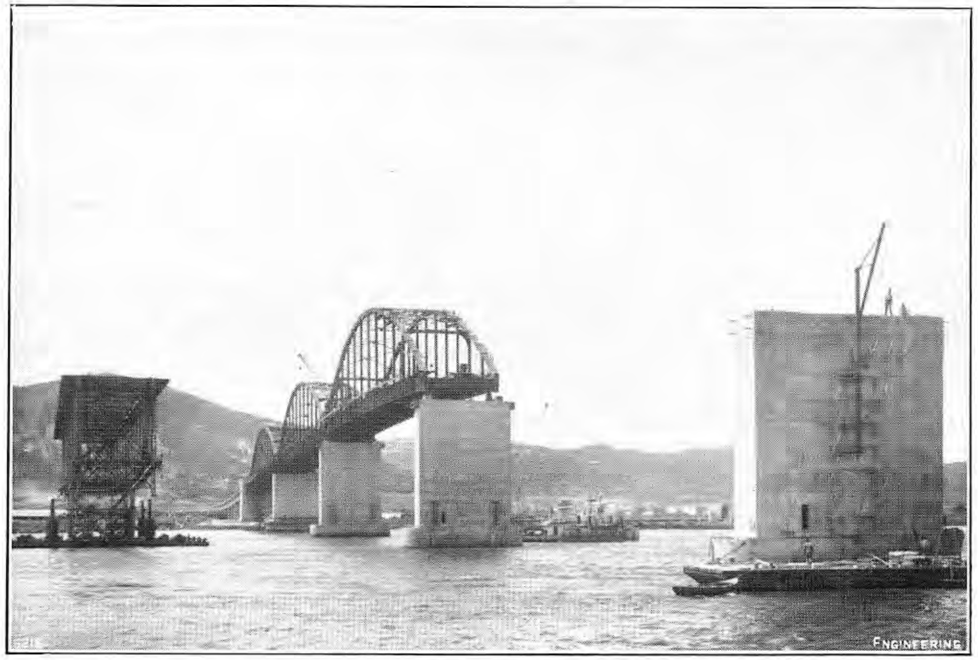


FIG. 31. SERVICE SPAN BEING REMOVED AFTER ERECTION OF SPAN "C."

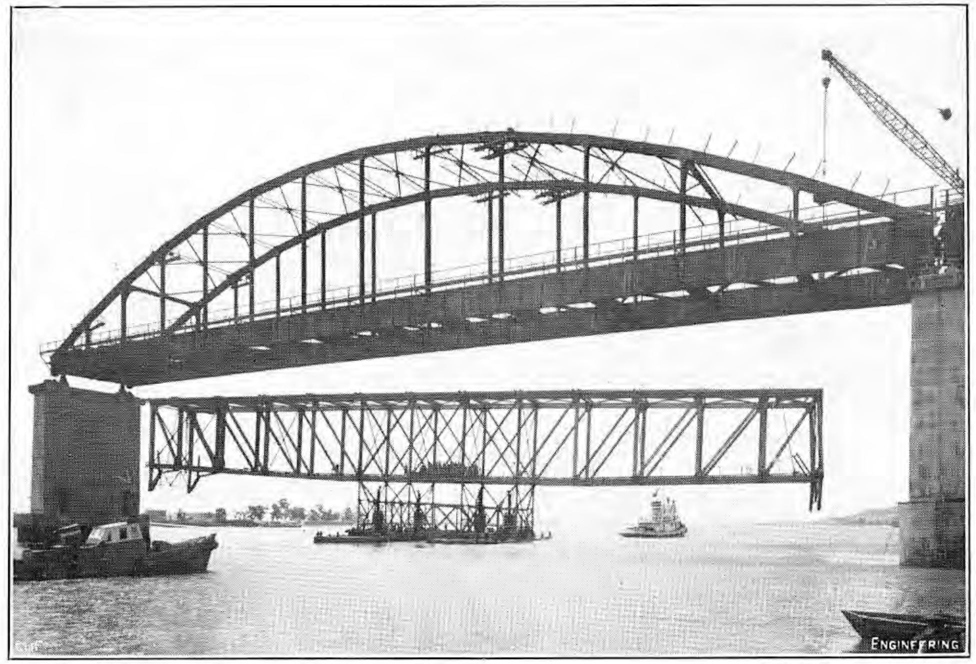


FIG. 32. SERVICE SPAN BEING MOVED FROM SPAN "C" TO SPAN "D."

FIG. 33. VIEW OF BRIDGE FROM VILA FRANCA SIDE WITH FOUR SPANS ERECTED.

FIG. 34. SERVICE SPAN IN POSITION FOR ERECTION OF LAST ARCH SPAN.

(*To face page* 803.)

ROAD BRIDGE OVER THE RIVER TAGUS.

DORMAN, LONG AND COMPANY, LIMITED, MIDDLESBROUGH.

FIG. 35. ERECTION OF LAST SPAN COMPLETED.

or Vila Franca, end of the bridge, and the four stages of the work of erecting the first span and placing the service span in position for the erection of the second span are illustrated diagrammatically in Figs. 22 to 25, opposite. Fig. 26 is a plan of the site and Figs. 27 and 28 show the general arrangement of the service span, the superstructure for supporting it on the barges and the method of supporting it on the plinths and of anchoring it at the tops of the piers. The operation of the scheme was complicated by the fact that, while the length of the openings between the piers is the same in each case, the height from the water level to the underside of the steelwork varies considerably, as will be clear on reference to Fig. 1, on Plate XLIX. Moreover, there is a tidal range of up to 4 m. (13 ft.) at the site and strong winds and tidal currents had also to be contended with. The weight of the service span was 380 tons and its overall length 325 ft. As it was only possible to provide a relatively small clearance between the ends of the span and the piers, it will be obvious that to manœuvre the span into position and lower it with precision on to the plinths of the piers involved some distinctly difficult problems in navigation. The removal of the service span into the next opening after the completion of one of the main spans was an even more difficult operation, because the service span had to be lowered clear while the permanent steelwork was still supported on jacks from the tops of the piers to enable the packings to be removed. Any delay in the removal of the service span on a rising tide would have resulted in its being trapped between the water and the permanent steelwork, with disastrous consequences. The whole of the erection work, however, was carried out without a hitch.

The two barges used for floating the service span into position were each of 500-tons capacity. They were towed to the site from Rotterdam, their hulls being specially reinforced to carry the heavy concentrated load of the service span. Upon and between the barges a steel superstructure was constructed and the height of this could be adjusted to suit the headroom available in the different openings. The general arrangement of the barge superstructure is indicated in Fig. 27, which shows it as adjusted for span C, the central opening of the bridge. The service span was first assembled on the barge superstructure at the contractors' wharf, shown on the right in Fig. 26. The barges carrying the service span were then towed out and manœuvred into position opposite the first bridge opening, at which point moorings attached to the river bed and the adjacent piers were taken up. At slack water low tide, the barges and their load were warped into position between the piers. Water was then admitted to the barges to lower them sufficiently to enable the ends of the service span to rest on its bearings on the plinths of the piers and then to enable the barges to be withdrawn from under the service span, which was left in position.

For the removal of the service span after the completion of the permanent span the operations outlined above were carried out in reverse order. As soon as the weight of the permanent span had been transferred from its temporary supports to the piers, all the packing on top of the service span was cleared away and the barges with their superstructures were warped into position under the service span at low tide and with the barges flooded to the maximum immersion. The barges were then raised into contact with the underside of the service span by pumping out the water ballast, careful adjustment of the moorings and special centring and locking devices ensuring that the barge superstructure made contact with the correct parts of the span. By pumping out more water ballast from the barges the service span was lifted and its weight transferred from the piers to the barges, which were then warped clear of the piers with the service span resting on them. The whole operation had, of course, to be carried out as rapidly as possible for the reason previously indicated. The utmost care was, of course, taken to ensure that the whole erection programme should be carried through without a hitch, as any damage to the barges or the service span would have seriously delayed the completion of the bridge, for which a period of 1,000 days was allowed from the date of signing the contract. This period expired on December 22, last, and the bridge was practically completed on that date. Fig. 35, on this page, is reproduced from a recent photograph showing the erection of the last arch span completed and the service span returned to the contractors' wharf for dismantling Photographs showing various earlier stages in the erection work are reproduced in Figs. 29 to 34, on Plates L and LI. The operations illustrated, we believe, will be readily understood with reference to the foregoing descriptive matter. As previously mentioned, the official opening will take place on Sunday next, the ceremony being performed by the President of the Republic, General Francisco Craveiro Lopes, assisted by the Minister of Public Works, Senhor José Frederico Ulrich.

Special attention was given to the protection of the steelwork of the bridge by painting. The steelwork, in this case, was delivered to the site and stacked in the stockyard before any painting had been done, time being allowed to enable the natural weathering action to loosen the mill scale. It was then cleaned by sand-blasting and the priming coat was applied within a few hours of the cleaning. Three further coats of paint were then applied at intervals. With the exception of about a dozen key men from the Dorman, Long Bridge Department, the whole of the work on the site was carried out by local labour. The contract, however, secured useful work in this country for the design staff of the Bridge Department, as well as for the steelworks and fabricating shops of the firm. Mr. J. F. Pain, a director of the Company, is manager of the Bridge Department and Mr. W. Cardno acted as agent of the Company at Vila Franca de Xira. Mr. D. H. Field was the engineer on the site.

LITERATURE.

Engineering Metrology.

BY K. J. HUME. Macdonald and Company (Publishers), Limited, 43, Ludgate Hill, London, E.C.4. [Price 18*s*. net.]

THE essential role of metrology in modern mechanical engineering has been emphasised during the past 20 years or so by significant changes in the physical approach to the problems of refined measurement, as well as by important advances in the techniques and apparatus used for their practical solution. The consequent need for a survey of present-day industrial equipment, correlated with its scientific background, has been most competently met by Mr. Hume, whose exceptional experience as Metrology Superintendent of the de Havilland Engine Company is supported by comprehensive theoretical knowledge and wide reading. He has, very sensibly, omitted any detailed treatment of the simplest instruments in everyday workshop use, preferring to enlarge on the less generally familiar metrological applications of geometry, optics, kinematic design and metallurgy. He writes instructively about such matters as the use of sensitive levels, the appraisal of surface finish, and the metrology of cutting tools and turbine blades. Frequent references to British Standards and to published accounts of original research enhance the value to students of a text which has been designed to cover the metrology syllabuses of the engineering institutions' examinations at Higher National Certificate level. Mr. Hume's thoroughness, however, has produced more than a text-book or a broad introduction, so that mechanical engineers or industrial administrators, concerned either directly or indirectly with refined measurement and its potential benefits, should find in his work a profitable source of information and reference.

Industrial Piping.

BY CHARLES T. LITTLETON. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 8 dols.]; and the McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 68s.].

To the British reader this American book will be found most useful as a work of reference, as it contains an unusually large number of tables of data on American sizes of pipes, flanges, etc.; such an amount of data has not previously been brought together in one volume. It must, however, be continually borne in mind by the British reader that the book is American, and he most not only avoid the old pitfall of American gallons, but remember that all the pipe sizes, etc., referred to are American sizes, not necessarily available in this country. The distinction between "pipe" and "tube," too, may not appeal to the British user. Nevertheless, such data are continually required when comparisons have to be made between American and British practice, and for this alone the book is valuable. As former engineer in charge of piping to the American Cyanamid Company, Mr. Littleton writes with authority.

The book opens with a description of drawing office practice and methods of designating pipework which, while potentially useful to a firm starting for the first time to deal with pipework, will probably have less appeal where there is an established drawing-office practice. There follow chapters on piping for steam, water, oil, gas, air, etc. There are, however, some curious omissions. For example, the chapter on steam piping makes no reference to high temperatures, nor to alloy steels or the effects of creep, though there is a table of allowable stresses, taken from American specifications, which naturally goes up to higher temperatures and covers some of the alloy steels; and, though many of the standard types of pipe are described, there is no reference to continuous-weld pipe, which forms such a large proportion of the pipe used both in this country and in America. Very little is said about concrete for water piping, and practically nothing about asbestos cement, though some other and much less common types of pipes are dealt with at length. The chapter on alloy piping refers almost exclusively to the use of such piping in connection with corrosive fluids, there being no reference to its use for high-temperature service. Steam traps and various types of valves, both for steam and water, are treated in great detail.

It seems a pity that the author should give so much prominence to the Hazen-Williams formula for the flow of water, which has little merit beyond that of frequent use in America. There are many better formulæ, or, if it is considered really necessary to use a formula in which a new coefficient has to be employed for almost every different condition, size of pipe, etc., there are other simpler formulæ which could be used. Similarly, in connection with oil piping, the Fanning formula is the one advocated, there being no reference to the much more recent work carried out by Moody and others on the effect of relative roughness. The author goes to some length in dealing with viscosity in an attempt to simplify this somewhat difficult subject, but he does not make it any easier by starting off with a wrong definition of the poise, nor does the reference to "slugs" improve matters so far as the average reader is concerned. There seems to be some confusion on page 152, where, in discussing viscous flow, an example is given in which turbulent flow is taking place. A more consistent use of units would also be an advantage, particularly on this same page, where D and *d* both appear to be used for the bore.

Under the heading of "Miscellaneous Piping Materials," there is considerable information on the subject of plastics, such as Saran, but it is not clear why, in the tables for Saran pipe and tubing, very different factors of safety are employed; the working pressure given in some cases is only about half the bursting pressure, whereas, in others, more reasonable factors of safety, of the order of 5, are employed. It is also curious to find that a Saran-lined steel tube is stated to be suitable for pressures up to 125 lb. per square inch, whereas the same size of plain Saran pipe can be used at 500 lb. per square inch. The details given for such unusual types of tube as Pyrex, graphite, glass-lined, etc., are useful and not otherwise readily available. After a chapter on pipe insulation, there is a special section on "Piping Cost Estimation." While the system proposed is an ingenious one, allowing rapid conversion of the cost of one size to the approximate cost of another size, we feel that any organisation dealing with piping costs is likely to have already a sufficiently accurate system available, so that they can make their estimates directly from the particular sizes involved; but the chapter may be of service to engineers who wish to prepare their own rough estimates as a check.

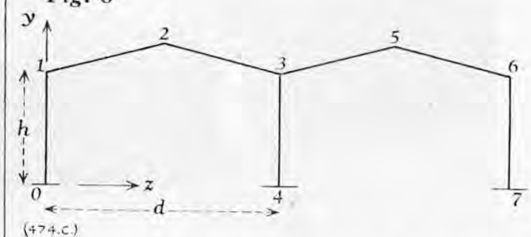
ELASTIC STRESS ANALYSIS OF MULTI-BAY SINGLE-STOREY FRAMEWORKS.

By E. H. BATEMAN, M.A., Ph.D.

(*Continued from page 774.*)

Numerical Example.—A symmetrical two-bay frame with vertical pillars and having the minimum number of frame members is chosen, because it illustrates the essential features of the problem without introducing heavy arithmetic. In developing the solution, the arithmetic is a little more complete than is necessary in a practical computation, in order to put on record a complete explanation of the process. On the other hand, the evaluation of moments and forces due to the loading required for a particular problem is not fully pursued, and the only such results given are for one applied moment, one horizontal load, and one vertical load. An interesting feature of the computation which may be specially noted is the high degree of accuracy obtained without retaining more significant figures than can be read from a slide rule, a result which would hardly be expected if the whole computation were undertaken in determinants instead of matrices.

Fig. 6



The framework which is outlined in the adjacent Fig. 6 can be completely specified by the tabulated geometrical and elastic data of the left-hand bay.

		0	1	2	3	4	Scale
Panel point		0	1	2	3	4	Scale
Co-ordinate	z	0	0	0·5	1·0	1·0	h
,,	y	0	1·0	1·3	1·0	0	d
Stiffness	μ		1·0	1·5	1·5	1·0	$\frac{h}{6\,EI}$

Equations (22) give the origin of the thrust axes

$$z_o = 0 \cdot 5$$

$$y_o = \frac{(0 + 2 \cdot 5 + \overline{1 \cdot 3 \times 3 \cdot 0} + 2 \cdot 5 + 0)}{10}$$

$$= 0 \cdot 89$$

The co-ordinates of the panel points relative to the thrust axes, H, V, are written down as follows, keeping the signs in the same sense as those of the geometrical datum co-ordinates :—

Panel point	0	1	2	3	4	Scale
Vertical co-ordinate	−0·89	0·11	0·41	0·11	−0·89	h
Horizontal co-ordinate	−0·50	−0·50	0	0·50	0·50	d

The directions of the thrust axes are now taken as shown in Fig. 7, herewith, in order to make the coefficients j, k, l take as far as possible the same signs as the panel-point co-ordinates

Now, following the convention of sign for the panel-point moments already established, i.e., a positive moment corresponding to a centre of curvature on the left of a pillar or above an arch member, and counting the right-hand pillar of the first bay as the left-hand pillar of the second bay, the equations of equilibrium, forming the matrix A, are as shown at the top of page 805.

Transposition of the equilibrium matrix, A, gives the conjugate matrices, A'_m and A'_n, the elements of which are tabulated below the relevant frame

Fig. 7.

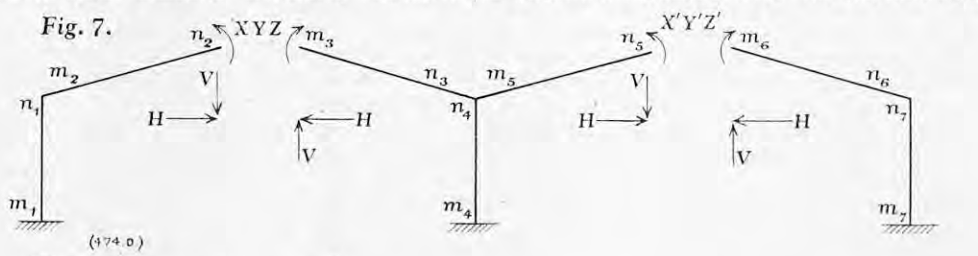
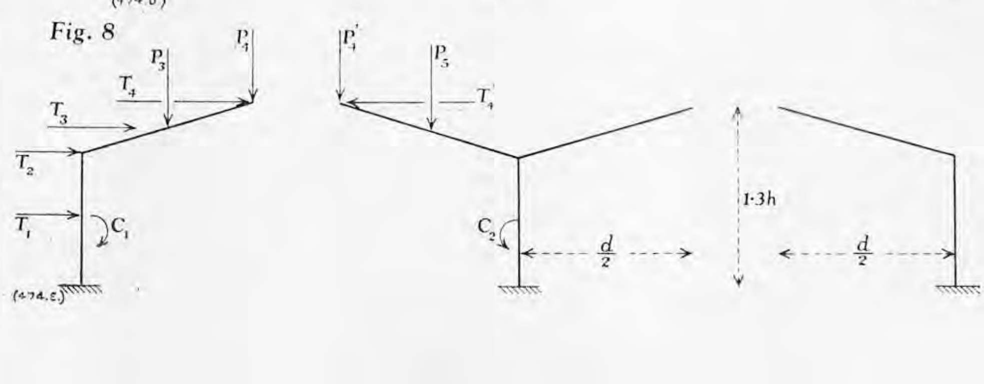


Fig. 8



$$
\mathrm{M(N)} - \mathrm{S} = \quad
\begin{array}{c}
\\ m1 \\ n1 \\ m2 \\ n2 \\ m3 \\ n3 \\ m4 \\ n4 \\ m5 \\ n5 \\ m6 \\ n6 \\ m7 \\ n7
\end{array}
\begin{array}{cccccc}
j\mathrm{X} & +k\mathrm{Y} & +l\mathrm{Z} & +j'\mathrm{X}' & +k'\mathrm{Y}' & +l'\mathrm{Z}' \\
\end{array}
$$

$$
\begin{array}{c}
m1 \\ n1 \\ m2 \\ n2 \\ m3 \\ n3 \\ m4 \\ n4 \\ m5 \\ n5 \\ m6 \\ n6 \\ m7 \\ n7
\end{array}
\left[\begin{array}{cccccc}
1 & -0\cdot89 & -0\cdot50 & & & \\
1 & 0\cdot11 & -0\cdot50 & & & \\
1 & 0\cdot11 & -0\cdot50 & & & \\
1 & 0\cdot41 & 0 & & & \\
1 & 0\cdot41 & 0 & & & \\
1 & 0\cdot11 & 0\cdot50 & & & \\
-1 & 0\cdot89 & -0\cdot50 & 1 & -0\cdot89 & -0\cdot50 \\
-1 & -0\cdot11 & -0\cdot50 & 1 & 0\cdot11 & -0\cdot50 \\
 & & & 1 & 0\cdot11 & -0\cdot50 \\
 & & & 1 & 0\cdot41 & 0 \\
 & & & 1 & 0\cdot41 & 0 \\
 & & & 1 & 0\cdot11 & 0\cdot50 \\
 & & & -1 & 0\cdot89 & -0\cdot50 \\
 & & & -1 & -0\cdot11 & -0\cdot50
\end{array}\right] = \mathrm{A}
$$

Frame member ...	(1)	(2)	(3)	(4)
Stiffness	1·0	1·5	1·5	1·0

$$
\mathrm{A}'_m\ (\mathrm{A}'_n) \ldots
\left[\begin{array}{ccccc}
1\cdot00\ (1\cdot00) & 1\cdot00\ (1\cdot00) & 1\cdot00\ (1\cdot00) & -1\cdot00\ (-1\cdot00) & \\
-0\cdot89\ (0\cdot11) & 0\cdot11\ (0\cdot41) & 0\cdot41\ (0\cdot11) & 0\cdot89\ (-0\cdot11) & \\
-0\cdot50\ (-0\cdot50) & -0\cdot50\ (0) & 0\quad (0\cdot50) & -0\cdot50\ (-0\cdot50) & \\
 & & & 1\cdot00\ (1\cdot00) & \ldots \\
 & & & -0\cdot89\ (0\cdot11) & \ldots \\
 & & & -0\cdot50\ (-0\cdot50) & \ldots
\end{array}\right]
$$

$$
\mathrm{B} = \left[\begin{array}{cccccccccc}
3\cdot00 & 3\cdot00 & 4\cdot50 & 4\cdot50 & 4\cdot50 & 4\cdot50 & -3\cdot00 & -3\cdot00 & . & . \\
-1\cdot67 & -0\cdot67 & 0\cdot95 & 1\cdot39 & 1\cdot39 & 0\cdot95 & 1\cdot67 & 0\cdot67 & . & . \\
-1\cdot50 & -1\cdot50 & -1\cdot50 & -0\cdot75 & 0\cdot75 & 1\cdot50 & -1\cdot50 & -1\cdot50 & . & . \\
 & & & & & & 3\cdot00 & 3\cdot00 & 4\cdot50 & \ldots \\
 & & & & & & -1\cdot67 & -0\cdot67 & 0\cdot95 & \ldots \\
 & & & & & & -1\cdot50 & -1\cdot50 & -1\cdot50 & \ldots
\end{array}\right]
$$

member and associated with the corresponding stiffness ratio, as shown in the table above. By reason of symmetry, the lower right-hand corner repeats the left-hand top corner as in the equilibrium matrix, since the framework is also elastically symmetrical.

The strain-energy matrix, B, can now be written down from the products, $\mu\,(2\,a_m + a_n)$ and $\mu\,(a_m + 2\,a_n)$, where a_m and a_n are corresponding elements of the conjugate matrices. This is shown above, where the lower right-hand block again repeats the upper left.

The operational matrix is now formed by taking the product B A, where B and A are the matrices found above. Thus

$$
\mathrm{Q} = \left[\begin{array}{cccccc}
30\cdot0 & . & . & -6\cdot00 & 2\cdot34 & 3\cdot00 \\
. & 4\cdot17 & . & 2\cdot34 & -1\cdot41 & -1\cdot17 \\
. & . & 4\cdot50 & -3\cdot00 & 1\cdot17 & 1\cdot50 \\
-6\cdot00 & 2\cdot34 & -3\cdot00 & 30\cdot0 & . & . \\
2\cdot34 & -1\cdot41 & 1\cdot17 & . & 4\cdot17 & . \\
3\cdot00 & -1\cdot17 & 1\cdot50 & . & . & 4\cdot50
\end{array}\right]
$$

In this matrix, the non-diagonal sub-matrices can be made identical by changing the signs in the sixth column and the sixth row. This transformation, which simplifies the subsequent arithmetic, can be effected by using a special unitary matrix J, which is defined by

$$
\mathrm{J} = \left[\begin{array}{cccccc}
1 & & & & & \\
 & 1 & & & & \\
 & & 1 & & & \\
 & & & 1 & & \\
 & & & & 1 & \\
 & & & & & -1
\end{array}\right]
$$

As the first factor in a product, in which the other factor is a square matrix of the same order, J reverses the signs of all elements in the last row; and, as the second factor, J reverses all the elements in the last column of the other factor. This special matrix has the useful property $\mathrm{J}^{-1} = \mathrm{J}$, or $\mathrm{J\,J} = \mathrm{I}$.

Equation (13), derived in the form

$$\mathrm{Q}\left\{\mathrm{X}\right\} = \mathrm{B}\left\{f, g\right\},$$

can therefore be written

$$\mathrm{J\,Q\,J\,J}\left\{\mathrm{X}\right\} = \mathrm{J\,B}\left\{f, g\right\},$$

or

$$\mathrm{R\,J}\left\{\mathrm{X}\right\} = \mathrm{J\,B}\left\{f, g\right\},$$

where $\mathrm{R} = \mathrm{J\,Q\,J}$ giving the solution in the form

$$\left\{\mathrm{X}\right\} = \mathrm{J}^{-1}\,\mathrm{R}^{-1}\,\mathrm{J\,B}\left\{f, g\right\}.$$

The operational matrix has been transformed into the symmetrical matrix

$$
\mathrm{R} = \mathrm{J\,Q\,J} = \left[\begin{array}{cccccc}
30\cdot0 & . & . & -6\cdot00 & 2\cdot34 & -3\cdot00 \\
. & 4\cdot17 & . & 2\cdot34 & -1\cdot41 & 1\cdot17 \\
. & . & 4\cdot50 & -3\cdot00 & 1\cdot17 & -1\cdot50 \\
-6\cdot00 & 2\cdot34 & -3\cdot00 & 30\cdot0 & . & . \\
2\cdot34 & -1\cdot41 & 1\cdot17 & . & 4\cdot17 & . \\
-3\cdot00 & 1\cdot17 & -1\cdot50 & . & . & 4\cdot50
\end{array}\right]
$$

Now, writing

$$
\mathrm{R}_1 = \mathrm{D\,R}, \text{ where } \mathrm{D} = \left[\begin{array}{ccc}
\frac{1}{30} & & \\
 & \frac{1}{4\cdot17} & \\
 & & \frac{1}{4\cdot5}
\end{array}\right]
$$

$$
\mathrm{R}_1 = \left[\begin{array}{cc} \mathrm{I} & \mathrm{E} \\ \mathrm{E} & \mathrm{I} \end{array}\right], \text{ where } \mathrm{E} = \left[\begin{array}{ccc}
-200 & 078 & -100 \\
561 & -338 & 280 \\
-667 & 260 & -333
\end{array}\right]
$$

omitting the decimal points in writing the elements of E. Then $\mathrm{R}^{-1} = \mathrm{R}_1^{-1}\,\mathrm{D}$.

The reciprocal matrix, R_1^{-1}, on which the solution now depends, is derived, as will be shown in Appendix I, in a convenient form for numerical computation, thus

$$
\mathrm{R}_1^{-1} = \left[\begin{array}{cc} \mathrm{C} & -\mathrm{E\,C} \\ -\mathrm{E\,C} & \mathrm{C} \end{array}\right], \text{ where } \mathrm{C} = (\mathrm{I} - \mathrm{E}^2)^{-1}
$$

a result which is easily verified by forming the product $\mathrm{R}_1\,\mathrm{R}_1^{-1}$. Hence,

$$
\mathrm{R}^{-1} = \left[\begin{array}{cc} \mathrm{C\,D} & -\mathrm{ECD} \\ -\mathrm{E\,C\,D} & \mathrm{C\,D} \end{array}\right]
$$

The arithmetical details are as follows

$$
\mathrm{E}^2 = \left[\begin{array}{ccc}
150 & -068 & 075 \\
-489 & 231 & -244 \\
501 & -227 & 250
\end{array}\right]
\qquad
\mathrm{I} - \mathrm{E}^2 = \left[\begin{array}{ccc}
850 & 068 & -075 \\
489 & 769 & 244 \\
-501 & 227 & 750
\end{array}\right]
$$

$$
\mathrm{Adj.}\ (\mathrm{I} - \mathrm{E}^2) = \left[\begin{array}{ccc}
521 & -489 & 496 \\
-068 & 600 & -227 \\
074 & -244 & 620
\end{array}\right]
\qquad
\mathrm{Det.}\ (\mathrm{I} - \mathrm{E}^2) = 0\cdot3725
$$

$$
\mathrm{C} = \left[\begin{array}{ccc}
1\cdot339 & -183 & 199 \\
-1\cdot313 & 1\cdot611 & -655 \\
1\cdot332 & -609 & 1\cdot665
\end{array}\right]
\qquad
\mathrm{E\,C} = \left[\begin{array}{ccc}
-515 & 223 & -237 \\
1\cdot602 & -818 & 799 \\
-1\cdot718 & 744 & -857
\end{array}\right]
$$

$$
\mathrm{C\,D} = \left[\begin{array}{ccc}
047 & -044 & 044 \\
-044 & 386 & -146 \\
044 & -146 & 370
\end{array}\right]
\qquad
\mathrm{E\,C\,D} = \left[\begin{array}{ccc}
-017 & 053 & -057 \\
053 & -196 & 178 \\
-057 & 178 & -190
\end{array}\right]
$$

$$
\mathrm{R}^{-1} = \left[\begin{array}{cccccc}
047 & -044 & 044 & 017 & -053 & 057 \\
-044 & 386 & -146 & -053 & 196 & -178 \\
044 & -146 & 370 & 057 & -178 & 190 \\
017 & -053 & 057 & 047 & -044 & 044 \\
-053 & 196 & -178 & -044 & 386 & -146 \\
057 & -178 & 190 & 044 & -146 & 370
\end{array}\right]
$$

$$
\mathrm{Q}^{-1} = \mathrm{J\,R}^{-1}\,\mathrm{J} = \left[\begin{array}{cccccc}
047 & -044 & 044 & 017 & -053 & -057 \\
-044 & 386 & -146 & -053 & 196 & 178 \\
044 & -146 & 370 & 057 & -178 & -190 \\
017 & -053 & 057 & 047 & -044 & -044 \\
-053 & 196 & -178 & -044 & 386 & 146 \\
-057 & 178 & -190 & -044 & 146 & 370
\end{array}\right]
$$

The solution matrix, Φ, can now be written down by forming the product, $\mathrm{Q}^{-1}\,\mathrm{B}$, which is a rectangular matrix of six rows corresponding to the six statically indeterminate quantities, X, Y, . . ., and 14 columns corresponding to the 14 known end fixing moments and panel-point moments of the applied forces, f_1, g_1, f_2, etc. For convenience of reference, the rows and columns of the solution matrix (top of page 806) are designated accordingly. The last six columns are omitted, since, in this symmetrical case, the effects of forces on the right-hand bay can be inferred by loading the left-hand bay and interchanging X, Y, Z, and X′, Y′, Z′.

The second matrix of the solution equations—i.e., A ϕ, which gives the end moments in each member—follows by straightforward computation. This is a square matrix of order 2R, which is 14 in this example. However, only part of it is normally required, especially if the number of frame members is large, since a design may be well based on the moments and forces at critical points only. For the same system of applied forces acting on the left-hand bay, the elements of A Φ required to solve for the moments in the three pillars and at the two apical points are as shown near the top of page 806. The diagonal elements are underlined to simplify the formation of the matrix difference (A Φ − I) which occurs in equation (26).

The applied loads have so far been described by f, g, where $f = \mathrm{F} - \mathrm{S}_m$, and $g = \mathrm{G} - \mathrm{S}_n$. Now F and G present no difficulty, since they are the end-fixing moments widely used in the elementary theory of structures. S_m and S_n have no such established and familiar meaning, and the formal definitions in equations (4) are therefore illustrated by tabulating their values for the typical loadings shown in Fig. 8, opposite.

In Table III, the elements of which constitute the applied loading matrix, the S component is shown above the F or G component of (f, g) and the F, G components are underlined with the decimal point omitted. T^x represents a uniformly distributed load with resultant T. The matrix is written as the conjugate of $[s', t, p]$ in equation (27), hence the rows are to be compounded with the rows of the solution matrices.

Since the arithmetical example is included to illustrate the method of analysis rather than as a design exercise, the final stage of computing thrust

TABLE III.—THE APPLIED LOADING MATRIX.

Load	f_1	g_1	f_2	g_2	f_3	g_3	f_4	g_4	Scale
T_1	−0·50	.	.	.	.	.	.	.	Th
	$-\underline{125}$	$-\underline{125}$							
T_1^x	−0·50	.	.	.	.	.	.	.	Th
	$-\underline{083}$	$-\underline{083}$							
T_2	−1·00	.	.	.	.	.	.	.	Th
T_3	−1·15	−0·15	−0·15	.	.	.	.	.	Th
			$-\underline{037}$	$-\underline{037}$					
T_4	−1·30	−0·30	−0·30	.	.	.	.	.	Th
T_4'	.	.	.	.	.	0·30	−1·30	−0·30	Th
P_3	−0·25	−0·25	−0·25	.	.	.	.	.	Pd
			$-\underline{063}$	$-\underline{063}$					
P_3^x	−0·25	−0·25	−0·25	.	.	.	.	.	Pd
			$-\underline{042}$	$-\underline{042}$					
P_4	−0·50	−0·50	−0·50	.	.	.	.	.	Pd
P_4'	.	.	.	.	.	−0·50	0·50	0·50	Pd
P_5	.	.	.	.	.	−0·25	0·25	0·25	Pd
					$-\underline{063}$	$-\underline{063}$			
P_5^x	.	.	.	.	.	−0·25	0·25	0·25	Pd
					$-\underline{042}$	$-\underline{042}$			
C_1	−1·00	.	.	.	.	.	.	.	C
	$\underline{250}$	$-\underline{250}$							
C_2	.	.	.	.	.	.	1·00	.	C
							$-\underline{250}$	$\underline{250}$	

$$\begin{array}{c} \\ \Phi = X \\ Y \\ Z \\ X' \\ Y' \\ Z' \end{array} \begin{array}{cccccccc} f_1 & g_1 & f_2 & g_2 & f_3 & g_3 & f_4 & g_4 \\ \end{array}$$

$$\Phi = \begin{array}{c} X \\ Y \\ Z \\ X' \\ Y' \\ Z' \end{array} \begin{bmatrix} 168 & 105 & 104 & 117 & 183 & 236 & -055 & -064 & \ldots \\ -558 & -172 & 388 & 448 & 229 & -050 & 242 & 052 & \ldots \\ -179 & -325 & -496 & -282 & 273 & 614 & -178 & -210 & \ldots \\ 054 & 011 & -059 & -040 & 046 & 117 & 055 & 064 & \ldots \\ -219 & -023 & 215 & 167 & -100 & -319 & -242 & -052 & \ldots \\ -183 & -005 & 198 & 133 & -152 & -372 & -178 & -210 & \ldots \end{bmatrix}$$

$$\begin{array}{cccccccc} f_1 & g_1 & f_2 & g_2 & f_3 & g_3 & f_4 & g_4 \end{array}$$

$$\underset{\text{(part)}}{A\Phi} = \begin{array}{c} M_1 \\ N_1 \\ M_3 \\ M_4 \\ N_4 \\ M_6 \\ M_7 \\ N_7 \end{array} \begin{bmatrix} \underline{734} & 421 & 007 & -141 & -157 & -026 & -181 & -005 & \ldots \\ 176 & \underline{249} & 395 & 307 & 072 & -077 & 061 & 047 & \ldots \\ -081 & 034 & 263 & 301 & \underline{277} & 216 & 044 & -043 & \ldots \\ -215 & -072 & 140 & 168 & 095 & -001 & \underline{719} & 431 & \ldots \\ 124 & 077 & -033 & -113 & -234 & -270 & 235 & \underline{327} & \ldots \\ -036 & -008 & 029 & 028 & 005 & -014 & -044 & 043 & \ldots \\ -157 & -019 & 151 & 122 & -059 & -215 & -181 & -005 & \ldots \\ 062 & 004 & -064 & -045 & 041 & 104 & 061 & 047 & \ldots \end{bmatrix}$$

moments and panel-point moments is limited to taking the effects of one vertical and two horizontal loads, and one moment. The results are given in Table IV, herewith.

TABLE IV.

	T_2.	T_4.	T'_4.	P_4.	P'_4.	C_1.
Y ...	−558	−661	345	−171	−172	−655
Z ...	−179	−479	−479	−500	501	−143
Y′ ...	−219	−227	−235	−014	−013	−268
Z′ ...	−183	−180	−183	005	008	−228
M_1 ...	−266	−217	−229	081	080	−188
N_1 ...	176	122	117	−090	−093	158
M_3 ...	−081	−016	−021	108	109	−110
M_4 ...	−215	−258	−244	−074	−076	−251
N_4 ...	124	174	185	084	084	136
M_6 ...	−036	−041	−040	−008	−006	−043
M_7 ...	−157	−165	−172	−013	−015	−192
N_7 ...	062	063	062	001	−002	077

The scale factors are T*h*, P*d* and C, as before. Comparison of the values of T_4 and P_4 with those for T'_4 and P'_4, obtained respectively from the left-hand and right-hand segments of the first bay, indicates the degree of accuracy which has been obtained by taking only two decimal places in matrix B and only three in the subsequent arithmetic. The errors are within one per cent. of the unit moments and, in most cases, are less than this, though some of the figures in B are only accurate within about a half of one per cent. Higher accuracy is easily obtained by computing matrix B more closely and retaining three decimal places after reducing to unity the largest element in each row. This step was omitted in order to retain symmetry in the elements of the operational matrix.

Appendix I. Matrix Inversion.—The method of forming the reciprocal of a square matrix of numerical elements is well known, and the same rules apply when the elements are common algebraic symbols or functions; but where the elements are matrices—and, of course, they must be square matrices of the same order—the primary rules only apply in a few special cases such as the following :—

$$S = \begin{bmatrix} I & A & . & . \\ A & I & A & . \\ . & A & I & A \\ . & . & A & I \end{bmatrix}$$

The general form of operational matrix occurring in the problem of the single-storey framework is

$$Q_1 = \begin{bmatrix} I & A_1 & . & . \\ B_1 & I & A_2 & . \\ . & B_2 & I & A_3 \\ . & . & B_3 & I \end{bmatrix}$$

Then assuming a reciprocal in the form

$$Q_1^{-1} = \begin{bmatrix} a_1 & a_2 & a_3 & a_4 \\ b_1 & b_2 & b_3 & b_4 \\ c_1 & c_2 & c_3 & c_4 \\ d_1 & d_2 & d_3 & d_4 \end{bmatrix}$$

formation of the product $Q_1^{-1} Q_1 = I$ gives sufficient equations for finding each of the elements in the reciprocal matrix. Results for the second-order and third-order matrices are

$$\begin{bmatrix} I & A \\ B & I \end{bmatrix}^{-1} = \begin{bmatrix} I + A\,C\,B, & -A\,C \\ -C\,B\,, & C \end{bmatrix}$$
$$= \begin{bmatrix} C', & -C'A \\ -B\,C', & I + B\,C'A \end{bmatrix}$$

where $C = (I - BA)^{-1}$, $C' = (I - AB)^{-1}$

$$\begin{bmatrix} I & A \\ A & I \end{bmatrix}^{-1} = \begin{bmatrix} C\;, & -A\,C' \\ -A\,C, & C \end{bmatrix}$$

where $C = (1 - A^2)^{-1}$

$$\begin{bmatrix} I & A_1 & . \\ B_1 & I & A_2 \\ . & B_2 & I \end{bmatrix}^{-1} = \begin{bmatrix} I + A_1\,C\,B_1, & -A_1\,C, & A_1 C\,A_2 \\ -C\,B_1\;, & C\;, & -C\,A_2 \\ B_2\,C\,B_1\;, & -B_2\,C, & I + B_2\,C\,A_2 \end{bmatrix}$$

where $C = (I - B_1A_1 - A_2B_2)^{-1}$

A convergent square matrix A may be defined by the equation

$$(I - A_1)^n = R \rightarrow 0, \quad . \quad . \quad (28)$$

where

$$A_1 = A_0\,A \quad . \quad . \quad . \quad (29)$$

and A_0 is the diagonal matrix of the reciprocals of the leading diagonal of A. In the particular case $A_1 = 1 + [a_{jk}]_r$, where $k = j \pm c$, and c is a fixed integer, it is easily seen that $R = O$, for any value of n greater than $r + 1 - c$. Generally, for matrices arising in the solution of engineering problems, the practical criterion for convergence is that the effects of the applied forces should decrease with distance from the point of application of an applied force. For the purpose of practical computation, it may be assumed that a value of n can be taken which will make R zero in equation (28), thus

$$(1 - A_1)^n = 0, \quad . \quad . \quad . \quad (30)$$

Hence,

$$I = I - (I - A_1)^n$$
$$= A_1(I + \overline{I - A_1} + \overline{I - A_1}^2 + \ldots) \quad (31)$$
$$A_1^{-1} = I + \overline{I - A_1} + \overline{I - A_1}^2 + \ldots \quad . \quad (32)$$

and

$$A^{-1} = A_1^{-1}\,A_0$$
$$= (I + S_1 + S_2 + S_3 + \ldots)\,A_0 \quad . \quad (33)$$

where

$$S_r = (I - A_1)^r$$

In computing the value of S(r), where

$$S(r) = I + S_1 + S_2 + \ldots + S_r, \quad . \quad (34)$$

it is unnecessary to evaluate all the terms in the series, since the procedure may be by successive approximation, thus

$$S(2) = I + S_1 + S_2, \quad . \quad . \quad (35)$$

which involves the one matrix product $S_2 = S_1^2$

$$S(4) = S(2) + S_2\,(S(2) - I), \quad . \quad (36)$$

involving one further matrix product; and taking the eighth approximation

$$S(8) = S(4) + S_4\,(S(4) - I), \quad . \quad (37)$$

which involves the two further matrix products $S_4 = S_2^2$ and $S_4\,(S(4) - 1)$. In many cases, S(4), which involves only two matrix products, will give sufficient accuracy for engineering design, and it should rarely be necessary to go beyond S(8).

An approximate solution may often be rapidly adjusted by the method of remainder distribution, which is particularly useful for the elimination of accidental errors arising in a computation. If X_1 is an approximate solution of the equations $A\,X = I$, a first remainder R_1 is given by the equation

$$A\,X_1 + R_1 = I\,. \quad . \quad . \quad . \quad (38)$$

A second approximation is then taken as

$$X_1 + X_2 = X_1 + X_1R_1. \quad . \quad . \quad (39)$$

The second remainder R_2 is given by

$$A\,(X_1 + X_2) + R_2 = I.$$

Thus,

$$A\,X_1 + A\,X_1\,R_1 + R_2 = I.$$

Hence, from (38)

$$R_2 = (I - A\,X_1)\,R_1$$
$$= R_1^2.$$

Successive remainders therefore occur in the form of a geometrical progression, and the convergence is very rapid if the elements of the first remainder are reasonably small in a matrix of limited size. Moreover, the computation is not heavy, since the elements of the remainders will generally involve only one or two significant figures and, in a typical calculation, many of the elements will be zero.

APPENDIX II.—*The Single-Bay Frame.*—Since the results obtained by the new method of analysis cannot easily be verified by existing analytical methods, a short example is added on the single-bay frame. The dimensions and stiffnesses are taken as in one bay of the two-bay framework. Proceeding as before with the construction of A and B, the dimensions of which are now 8 by 3 instead of 14 by 6, and then forming the product B A, for the operational matrix Q, we find

$$Q = \begin{bmatrix} 30 \cdot 0 & . & . \\ . & 4 \cdot 17 & . \\ . & . & 4 \cdot 5 \end{bmatrix}$$

$$B = \begin{bmatrix} 3 \cdot 00 & 3 \cdot 00 & 4 \cdot 50 & 4 \cdot 50 & \ldots \\ -1 \cdot 67 & -0 \cdot 67 & 0 \cdot 95 & 1 \cdot 39 & \ldots \\ -1 \cdot 50 & -1 \cdot 50 & -1 \cdot 50 & -0 \cdot 75 & \ldots \end{bmatrix}$$

In this form, Q can be immediately inverted and Φ written down, thus

$$\Phi = Q^1\,B =$$
$$\begin{bmatrix} 100 & 100 & 150 & 150 & 150 & 150 & -100 & -100 \\ -400 & -160 & 227 & 333 & 333 & 227 & 400 & 160 \\ -333 & -333 & -333 & -167 & 167 & 333 & -333 & -333 \end{bmatrix}$$

omitting the decimal points, as in the previous arithmetic. Then (see at foot of first and second columns).

$$\begin{array}{cccccccc} f_1 & g_1 & f_2 & g_2 & f_3 & g_3 & f_4 & g_4 \end{array}$$

$$\underset{\text{(part)}}{A\Phi} = \begin{array}{c} M_1 \\ N_1 \\ M_3 \\ M_4 \\ N_4 \end{array} \begin{bmatrix} \underline{623} & 409 & 114 & -063 & -230 & -219 & -290 & -076 \\ 223 & \underline{249} & 341 & 270 & 103 & 008 & 111 & 084 \\ -064 & 034 & 243 & 287 & \underline{287} & 243 & 064 & -034 \\ -290 & -076 & 219 & 230 & 063 & -114 & \underline{623} & 409 \\ 111 & 084 & -008 & -103 & -270 & -341 & 223 & \underline{249} \end{bmatrix}$$

Now, using the applied loading matrix in Table III, the panel-point moments due to loads T_2, T_4, P_4, and C_1 are found to have the values given in Table V.

TABLE V.

	T_2	T_4	P_4	C_1
M_1	−377	−333	073	−323
N_1	223	167	−093	216
M_3	−064	0	106	−088
M_4	−290	−334	−073	−343
N_4	111	167	093	118
Scale	Th	Th	Pd	C

OBTAINING PRESSURE DIAGRAMS OF INTERNAL-COMBUSTION ENGINES.*

By A. J. CORNISH and W. P. MANSFIELD, B.Sc.(Eng.).

A PRECISE knowledge of the gas-pressure changes which occur during the working cycle is of great value in the study of reciprocating internal-combustion engines. Thus, from a sufficiently accurate cylinder-pressure diagram a large amount of information can be derived relating to such matters as the exchange of heat between the contents of the cylinder and the cylinder walls during the compression and expansion processes, the complex process of combustion, and the many actions which occur during the gas exchange process. Moreover, such a diagram enables the indicated horse-power to be assessed, so that a true measure of mechanical efficiency may be obtained, while the harmonic analysis of the resultant torque diagram gives the contribution of the gas pressure to the forces exciting torsional vibration. For all work of this kind a high degree of accuracy is required, and it is very desirable that the pressure diagram should be obtainable in a few minutes. None of the methods in general use is satisfactory in both respects.

The cathode-ray oscillograph type of engine indicator has proved to be a powerful aid in the qualitative study of the various phenomena associated with internal-combustion engines. Its versatility has tended to obscure its present limitations for quantitative work,

* Research Report 51/5, "Methods used at the B.I.C.E.R.A. Laboratory for Obtaining Pressure Diagrams," published by the British Internal Combustion Engine Research Association, 111-112, Buckingham-avenue, Slough, Buckinghamshire.

OBTAINING PRESSURE DIAGRAMS OF ENGINES.

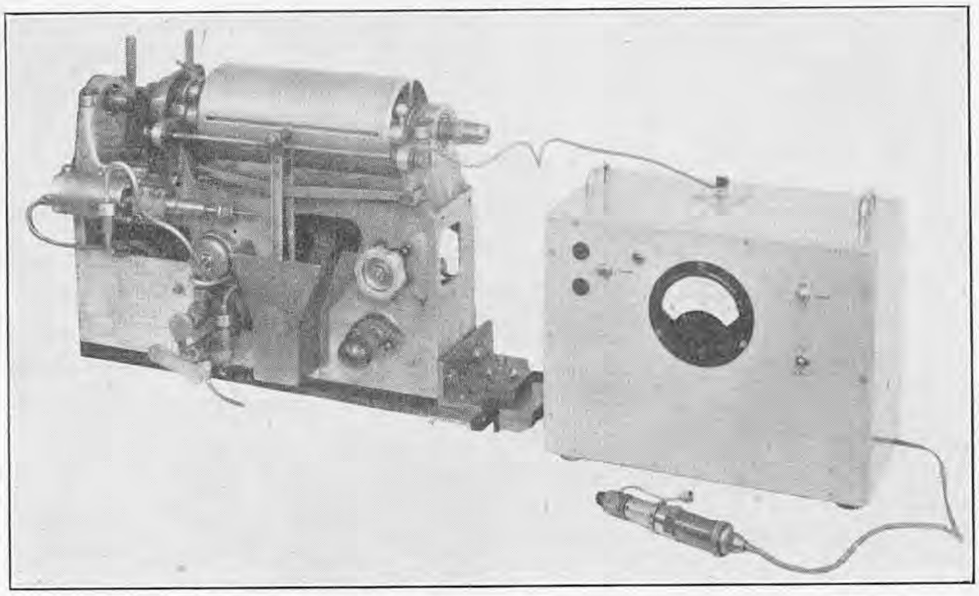
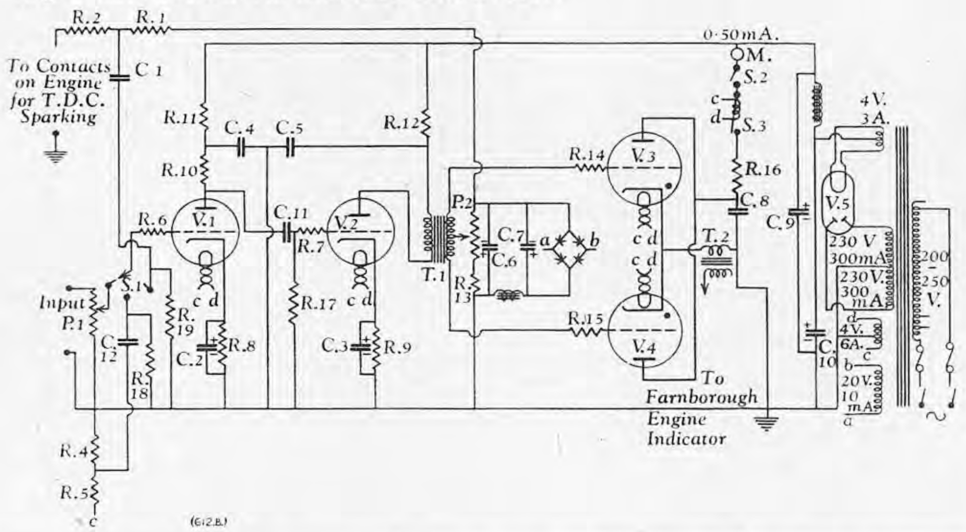


FIG. 1. B.I.C.E.R.A. ENGINE INDICATING SYSTEM NO. 1.

Fig. 2 CIRCUIT DIAGRAM OF THYRATRON CONTROL UNIT.



V. 1 and 2 ..	Osram M.H.4	C. 9 and 10 ..	Elec. 16 μF. 500 V.	R. 14 and 15 ..	2,000 Ω ½ W.
V. 3 and 4 .. V. 5 ..	Osram G.T.I.C. .. .. Osram M.U. 14	C. 11 .. .. R. 1, 17, 18 and 19	2 M.F. 250 V. .. 100,000 Ω ½ W. ..	R. 16 ..	3,500 Ω, wire-wound 10 W. non-inductive.
P. 1 .. P. 2 ..	Carbon track, 10,000 Ω .. Wire wound 10,000 Ω ..	R. 2 .. .. R.	5,000 Ω ½ W. .. 100 Ω ½ W. ..	T. 1	Varley class " B " input transformer, type D.P.41, 3 : 1 and 4 : 1 ratio each half.
C. 1 and 12	0·001 μ F.	R. 5	300 Ω ½ W. ..	T. 2	6 V. ignition coil.
C. 2 and 3 ..	Elec. 100 μ F. 12 V. ..	R. 6 and 7 ..	15,000 Ω ½ W. ..	S. 1	S.P. 3 way.
C. 4 and 5	Elec. 4 μ F. 500 V. ..	R. 8 and 9 ..	1,100 Ω ½ W. ..	S. 2	S.P. St.
C. 6 and 7	Elec. 100 μ F. 25 V. ..	R. 10, 11 and 12	60,000 Ω 1 W. ..	S. 3	Thermal delay Sw.
C. 8 ..	0·25 μ F. 800 V. ..	R. 13	7,000 Ω ½ W. ..		

though they are recognised by some writers.* The smallness of inertia effects, when a suitable pick-up diaphragm is used, makes possible the indication of pressure changes at very high frequencies, so that, for the study of detonation in petrol engines or combustion knock in Diesel engines, this type of equipment is by far the most suitable.

When, however, a cylinder-pressure diagram is required for such purposes as the determination of the harmonic components of the gas-pressure torque or the indicated horse-power, the diagram obtained on the screen of the cathode-ray tube is of little value, because the ordinates and abscissae are not proportional to the pressure and time with the required degree of accuracy. The most suitable equipment in this respect, tested in the laboratory, is the Southern Instruments engine indicator, in which the proportionality of the tube deflection voltage to the pressure applied to the pick-up approaches the required accuracy and to which, no doubt, further improvements are possible. By using a drum-type camera with this equipment, the diagrams may be recorded against a time base which is linear to the required degree of accuracy. The errors in the ordinates of the diagrams are partly due to lack of linearity in the response of the pick-up and associated circuits, and partly to non-linear effects in the cathode-ray tube. The curvature of the screen of the tube introduces a serious error when the diagram is photographed. Here again, further improvements are to be expected. A promising development in the direction of greater accuracy of the pick-up and associated circuits is the Li catenary-diaphragm pick-up and amplifier.*

The most promising alternative to the cathode-ray oscillograph with diaphragm-type pick-up is the balanced-pressure type of indicator, of which the Farnboro' is the earliest and best known. This form of the apparatus, however, has serious limitations. The disc valve, which moves when pressure balance occurs, is arranged as a switch in the low-tension circuit of a sparking coil. The contact surfaces of this switch are in communication with the combustion chamber, and when in use become fouled rapidly, especially in a Diesel engine. The slightest deposition of carbon or lacquer produces irregular behaviour of the switch, and consequently a scatter of the points recorded on the diagram. The disc valve, weighing $\frac{1}{12}$ oz., is heavier than would at first appear necessary. It seems likely that a certain impact force is necessary to produce effective contact when some deposition has occurred. Even with the comparatively heavy valve provided, however, sparking ceases entirely when a moderate carbon deposit has formed. The scatter is not due solely to carbon deposition however. When the contact surfaces are kept clean, as for example in taking diagrams of the pressure changes in the induction passage of an engine, a considerable scatter of points occurs, which thus appears inherent in this system. When the standard 6 volts are used across the switch, the effects of arcing on the contact surfaces are apparent, especially when the unit is used for " light spring " work, and the disc valve may even become welded to one of the seats. The voltage cannot be reduced below 4 volts in the standard equipment since sparking ceases below this value, and it appears likely that some tendency to arcing is still present. This arcing probably accounts for the scatter.

In a much more precise technique developed by Stansfield* a small disc $\frac{5}{16}$ in. in diameter, of the order of 0·020 in. thick according to the application, is used as a disc valve, and its movement is indicated by means of an electromagnetic pick-up and an oscillograph. With this system there is apparently no scatter other than that due to actual variations of the pressure diagram from cycle to cycle. No arcing occurs, since the disc is not used as a contact breaker, and deposition of carbon has no effect on the accuracy of the indication of the moment of pressure balance until a very heavy deposit, sufficient to take up the working clearances, has formed, a process which would take many hours of running. In an exceptional circumstance, deposition of soft lacquer has been known to affect the behaviour of the unit. A simple check of the action of the unit at the end of a period of use, by applying a very small pressure difference, suffices to show whether or not the disc is perfectly free and the indications reliable.

As far as the majority of pressure diagrams are concerned, inertia effects are negligible. A typical disc valve, 0·018 in. thick, weighs only 0·002 oz. and has a mass per unit of exposed area less than a fifth of that of the Farnboro' disc valve. The disc valve cannot respond satisfactorily, however, to high-frequency pressure oscillations such as occur during knocking in a Diesel engine, or detonation in a petrol engine. The method has been widely used not only to record pressure diagrams in various parts of engines, compressors, and the like, but also to calibrate the diagrams produced by various indicators of the cathode-ray oscillograph type employing diaphragm pick-ups, a tribute to its accuracy. The Torsional Vibration Panel of the Association has regarded this as the only acceptable method of recording cylinder pressure curves for harmonic analysis.†

Until recently the procedure employed in the laboratory has been as follows. The output of the Sunbury disc-valve unit and the output of the degree-scale pick-up unit are switched into the amplifier of a Sunbury engine indicator together so that a combined diagram is obtained. With a suitable setting of the time-base " spread " controls, the point at which the disc-valve diagram breaks away from the degree scale may be read off to a fraction of a degree; thus errors which would arise in transferring measurements from the disc-valve diagram to the degree scale are avoided. The combined diagrams obtained with a series of known applied pressures are photographed on 35-mm. film, the frames of which are subsequently studied in a microfilm reader, the points obtained being plotted directly. This procedure has the advantage that the engine running time taken to obtain the necessary records is reduced to a minimum, and the records may be analysed accurately in quiet surroundings. The great disadvantage of this method is the long time taken to produce a diagram. If the pressure undergoes a large number of fluctuations during a single cycle, as may be the case in the inlet or exhaust system of an engine, each diagram may take a total of three hours or more to produce.

A need was thus apparent for an automatic means of plotting the timing indications produced by the Sunbury disc-valve unit against the values of the pressure applied to the unit. Various methods of achieving

* " Engineers' Problems in the Measurement of Stress and Pressure," by J. G. G. Hempson. ENGINEERING, vol. 166, page 425 (1948).

* " A New High-Performance Engine Indicator of the S.G. Type," by C. S. Draper and Y. T. Li. *Jl. Inst. Aeronautical Sciences*, October, 1949.

* " Pressure Indicating for Internal-Combustion Engines," by R. Stansfield and A. G. Withers. *The Engineer*, pages 152, 178 and 208, vol. 186 (1948).

† *Harmonic Components for High-Speed Four-Stroke Cycle Diesel Engines.* B.I.C.E.R.A. Report No. 48/4.

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Fig. 3. CYLINDER PRESSURE DIAGRAM PRODUCED BY B.I.C.E.R.A. INDICATING SYSTEM

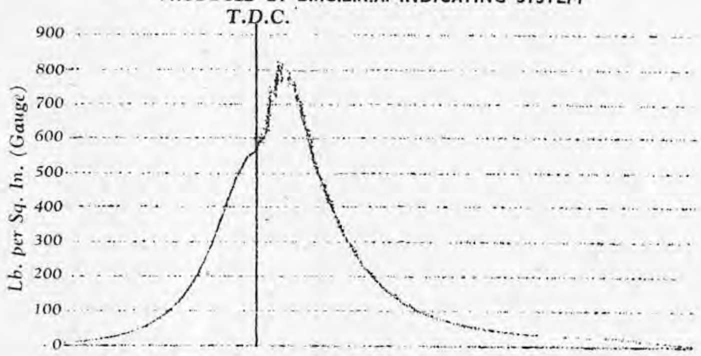


Fig. 4. CORRESPONDING CYLINDER-PRESSURE DIAGRAM PRODUCED BY FARNBORO'

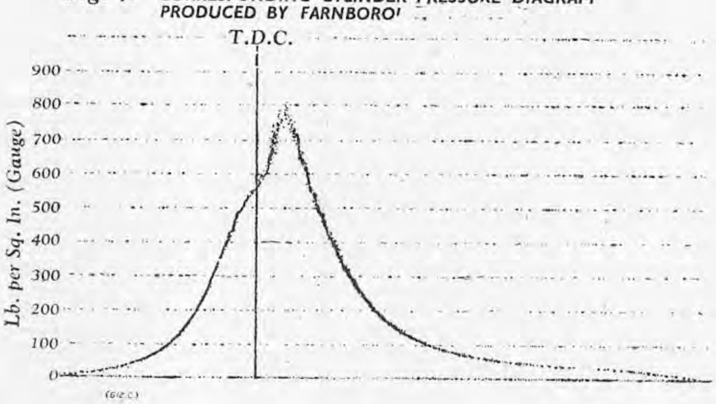


Fig. 5. INLET-PRESSURE DIAGRAM PRODUCED BY B.I.C.E.R.A. INDICATING SYSTEM.

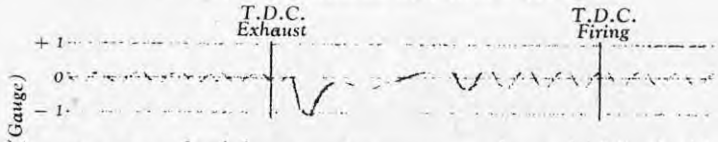
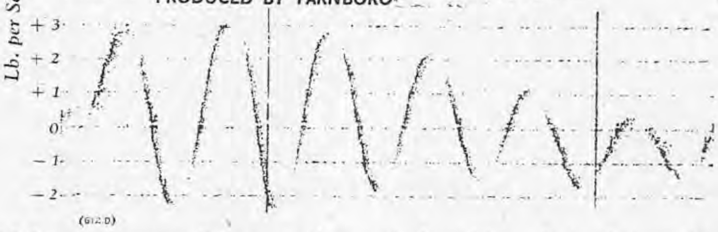


Fig. 6. CORRESPONDING INLET-PRESSURE DIAGRAM PRODUCED BY FARNBORO'

Fig. 7. EXHAUST-PRESSURE DIAGRAM PRODUCED BY B.I.C.E.R.A. INDICATING SYSTEM.

Fig. 8. CORRESPONDING EXHAUST-PRESSURE DIAGRAM PRODUCED BY FARNBORO'



this result were considered. A truly linear time-base was essential, and a drum driven by the engine appeared the most certain way of obtaining this. This led to further consideration of the Farnboro' indicator, which has a suitable drum, clutch, and brake. It was apparent that the air cylinder, springs, and linkage system of the Farnboro' were capable of giving a movement proportional to pressure with a high degree of accuracy, given correct adjustment; and, moreover, the spark method of recording the instant of pressure balance appeared satisfactory. The problem thus resolved itself into one of controlling the sparks for the Farnboro' indicator by means of the Sunbury disc-valve unit. It was proposed that the electromotive force produced by the Sunbury disc-valve unit should be applied, after amplification, to the grid of a thyratron valve used to release pulses of current into the primary winding of the sparking coil.

A number of circuits based on this principle were tested, and a satisfactory one was found, and developed. All the components necessary to couple the Sunbury disc-valve unit with the Farnboro' recording unit were housed in a case measuring 13½ in. by 9 in. by 10 in., visible in Fig. 1, on page 807, which shows the complete equipment. They were connected as shown in the circuit diagram Fig. 2. The output of the disc-valve unit is amplified by a two-stage resistance-capacity coupled amplifier, and then passed to the primary winding of a Class B transformer. The secondary of this transformer is centre-tapped and the output is applied to the grids of two thyratrons. Flow of current in either direction in the primary of the transformer, resulting from movement of the disc valve in either direction, raises the grid voltage of one or the other of the two thyratrons above the critical control voltage, thereby discharging a condenser, the discharge current passing through the primary of a sparking coil.

One end of the secondary winding of the sparking coil is earthed in the normal manner and the other is connected to the Farnboro' recording unit. The circuit also embodies refinements such as decoupling between the two stages of the amplifier, means for adjusting the control voltages of the thyratron, and a thermal delay switch to prevent high anode voltage being applied to either thyratron before the cathode temperature has been raised sufficiently by the heater. A suitable high-tension unit, comprising transformer, valve rectifier and smoothing devices, is incorporated to permit operation from 230-volt 50-cycle mains.

Figs. 3, 5 and 7 show examples of the diagrams produced by the new system, while Figs. 4, 6 and 8 are the corresponding diagrams given by the normal Farnboro' equipment. In order to obtain the best possible diagrams by the Farnboro' method, several special steps were taken. The normal end cap of the Farnboro' disc-valve unit, which has an unnecessarily long passage likely to produce scatter on the diagram by wave action, was replaced by a specially-made cap having a passage of small dimensions similar to those of the Sunbury unit. Great care was exercised in the preparation of the disc-valve unit, the valve being lapped on to its seatings before each test, and the cleaned unit was in operation for a few seconds only before each diagram was recorded, the engine being fully warmed up before shutting down and fitting the disc-valve unit. When the inlet diagram was recorded, the minimum voltage (4 volts) required to produce sparking at the recording drum was employed instead of the standard 6 volts, and this reduced the scatter. For the low-pressure diagrams, the specially-constructed large air piston and cylinder shown in Fig. 9, opposite, and visible in Fig. 1, were used with both methods to minimise frictional effects.

The diagrams produced by the new method were checked by the points obtained by the normal Sunbury disc-valve method using the cathode-ray oscillograph, and no significant discrepancies were found. It should be noted that the small missing portions of the diagrams are those at which the Sunbury disc-valve unit does not give a clear indication and which therefore cannot be obtained satisfactorily by the point-by-point method. It is clear that there will usually be very little doubt as to the course of the diagram at such places. The pressure calibration lines shown on the diagrams were produced by a method similar to that which has sometimes been used in the past with the normal Farnboro' indicator. A suitable steady pressure measured by an accurate Bourdon-type gauge or liquid manometer is applied to the piston of the indicator in the normal manner, and as the drum rotates a succession of sparks is passed through the paper, producing a straight line across the diagram. This process is repeated at a suitable number of pressures covering the pressure range of the diagram. With the normal Farnboro' indicator a simple buzzer is connected in place of the disc-valve unit to make and break the primary current of the sparking coil. In the B.I.C.E.R.A. system, by the operation of a switch on the thyratron control unit, a signal is taken from the 50-cycle mains and applied to the circuit in place of the signal from the disc valve.

Accurate marking of the top dead-centre (T.D.C.) lines or other timing marks on the diagram is also essential, since small errors in this respect produce large errors in the derived torque curves and the values obtained for indicated horse-powers. On the Farnboro' indicator, provision is made for drawing across the drum a line which lies against the point of the spark electrode when the engine is turned to top dead-centre. Alternatively, the line may be sparked across the paper with the drum clutch engaged and the engine set at the required position. It is obvious that an interval of time must elapse between the moment of pressure balance at the disc valve, and the passage of the spark through the recording paper, so that a timing line obtained in the above manner cannot be strictly accurate in relation to the diagram.

When the B.I.C.E.R.A. diagrams shown in Figs. 3, 5 and 7 were recorded, the top dead-centre lines were sparked on while the engine was running, using a contact-breaker on the flywheel to pass a signal to the thyratron control unit precisely at the top dead-centre position of the engine. This made due allowance for the delay between the application of a sufficient voltage to the thyratron control unit and the passage of the spark. The line thus obtained coincided with that sparked with the engine at rest. Using this timing line, the diagrams were found to be in agreement with points obtained with the same disc-valve unit by the point-by-point method, the degree scale being set, in accordance with the latest recommendation, with the 90-deg. slot symmetrically disposed about the centre-line of the pole-piece of the degree marker pick-up. It was concluded that the method gave the same accuracy as the Sunbury point-by-point method, so that the object of the work had been achieved.

In order to permit still more accurate determinations, and to cater for the indication of engines running at speeds higher than the 1,200 r.p.m. used, tests were made to measure the actual period of delay. The delay period between the application of a sufficient voltage to the grid of the thyratron and the passage of the spark was first measured by arranging a contact-breaker, driven by an electric motor, to apply an ample voltage from a battery to the thyratron control unit. The same signal was passed to a cathode-ray oscillograph, and on the trace produced was superimposed a signal obtained by induction from the sparks produced by the control unit. The interval between these signals was found to be 0·016 milliseconds, corresponding to 0·11 deg. of crank angle at 1,200 r.p.m. This accounted for the apparent coincidence of the top dead-centre lines obtained statically and by the contact-breaker on the flywheel. It is clear that, in addition to this delay, there must be some delay before the disc-valve unit produces sufficient voltage to operate the thyratron. To measure the total delay, the amplified output of the Sunbury balanced disc-valve unit was applied without integration to a cathode-ray oscillograph using a very large "spread" of the time-base. The output of the pick-up, which was mounted in an engine cylinder, was also applied in the normal way to the thyratron control unit operating the Farnboro' recording unit. A signal obtained by induction from the sparks of the Farnboro' was superimposed on the input from the pick-up to the oscillograph. The diagram thus produced showed the initial

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Fig. 9. SPECIAL AIR PISTON AND CYLINDER FOR LOW-PRESSURE DIAGRAMS.

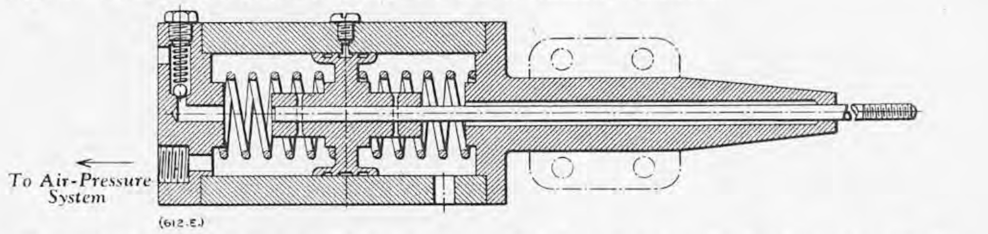


Fig. 14. APPLICATION OF STEM CONDENSER-TYPE DISC-VALVE UNIT.

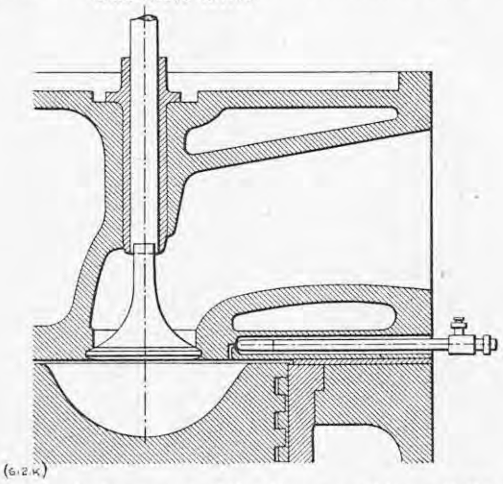


Fig. 10. RELATIONSHIP BETWEEN DELAY PERIOD AND RATE OF PRESSURE CHANGE.

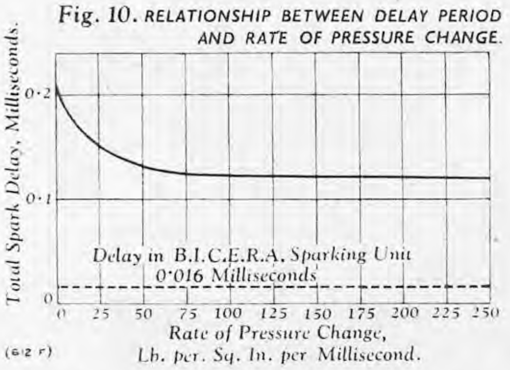


Fig. 12. INPUT CIRCUIT FOR CONDENSER-TYPE DISC-VALVE UNIT.

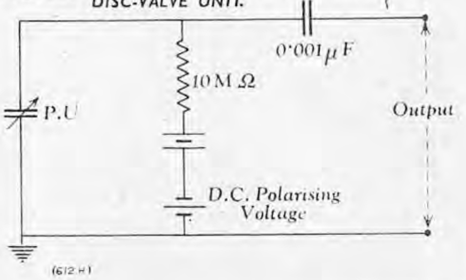


Fig. 11. ARRANGEMENT OF STEM CONDENSER-TYPE DISC-VALVE UNIT.

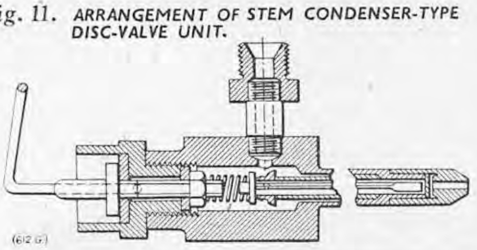
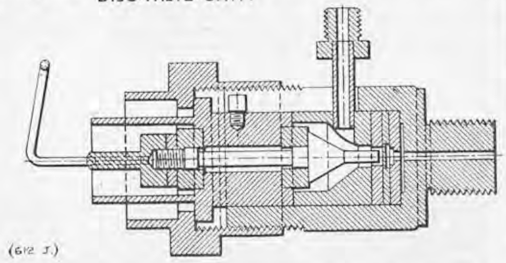


Fig. 13. ARRANGEMENT OF SHORT CONDENSER-TYPE DISC-VALVE UNIT.



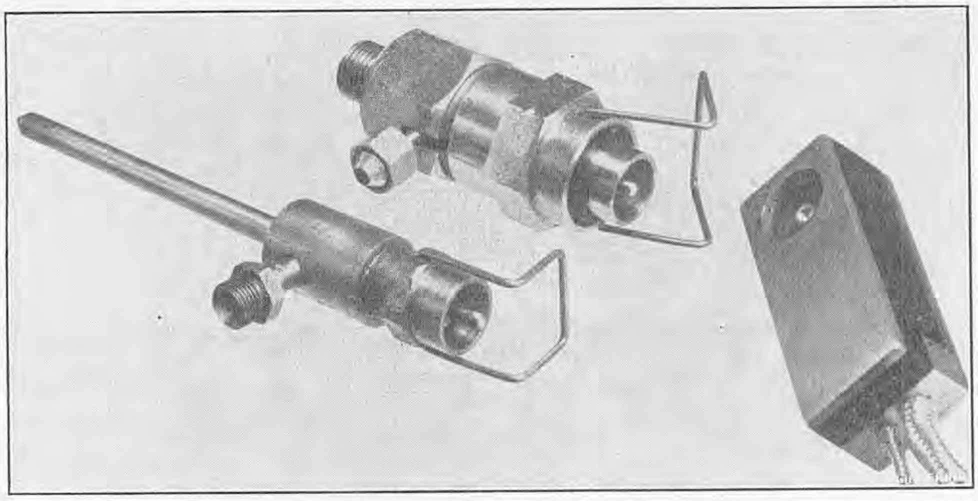


FIG. 15. STEM AND SHORT CONDENSER-TYPE DISC-VALVE UNITS.

movement of the disc valve and then an almost vertical deflection of the spot due to the signal from the spark. The distance between the first perceptible rise of the disc-valve lift diagram away from its base, and the spark line, was taken as a measure of the total delay period. The normal degree scale obtained with the Sunbury time-sweep unit driven by the engine was used as a time-base. The measurement was made at various rates of pressure change (determined by drawing tangents to the corresponding sparked diagram), with the results shown in Fig. 10.

At rates of pressure change above 50 lb. per square inch per millisecond, the total delay time may be taken as constant at 0·124 milliseconds, which corresponds to 0·89 deg. of crank angle at 1,200 r.p.m. This is represented by a horizontal distance of 0·017 in. in Fig. 3, equal approximately to the thickness of the fine compression line. On this diagram, the rate of change of pressure of 50 lb. per square inch per millisecond is reached at 160 lb. per square inch on the compression line and at 240 lb. per square inch on the expansion line. Between 50 lb. per square inch per millisecond and a pressure-change rate close to zero, the delay time rises from 0·124 to 0·21 millisecond, i.e., from 0·89 to 1·51 deg. of crank angle at 1,200 r.p.m. In spite of this increase in the delay time, the error in the diagram in terms of pressure becomes progressively less as the slope of the diagram diminishes. Thus, on the cylinder-pressure diagram, Fig. 3, a rate of 1 lb. per square inch per millisecond occurs at the extreme left-hand side of the diagram; and the time delay (0·2 millisecond) obtained with this rate, corresponding to 1·44 deg. or 0·028 in. on the horizontal scale of the diagram, produces a negligible error in the pressure, since this part of the diagram is almost horizontal.

On the low-pressure diagrams, Figs. 5 and 7, the maximum rates of pressure change are of the order of 1 lb. per square inch per millisecond, so that the time delay for all points is close to 0·2 millisecond, 1·44 deg. at 1,200 r.p.m., which on these diagrams (in which the time-base represents 720 deg. of crankshaft revolution) corresponds to a horizontal distance of 0·014 in., which is less than the thickness of the trace. From these findings, it appears that for some purposes it may be unnecessary to apply any correction. In most other cases it will be sufficient to apply a common correction to all points on the diagram by drawing a new T.D.C. line alongside the line sparked with the engine stationary at T.D.C. The distance between the two lines should correspond to a delay time judged from Fig. 10, having in mind the approximate range of rates of change of pressure in the diagram recorded. Thus, if the T.D.C. line of Fig. 3 is moved to the right (since all the points on the diagram are recorded slightly late) by an amount corresponding to 0·124 millisecond, there will be no error in the portion of the diagram above 250 lb. per square inch. The error in the lower part of the diagram will be negligible for most purposes. In the case of low-pressure diagrams such as Figs. 5 and 7, displacement of the T.D.C. lines by an amount corresponding to 0·2 millisecond will correct the whole diagram. When the very greatest possible accuracy is required, or speeds much higher than 1,200 r.p.m. are used, a sufficient number of corrected points may be marked alongside the sparked diagram, the correction appropriate to the rate of change of pressure being applied to each point.

To justify such corrections it would be necessary to determine the top dead-centre position of the engine with comparable accuracy, and to ensure that relative rotational movement between the Farnboro' drum and the engine crankshaft, due either to flexibility or back-lash in the clutch and the connections used, was correspondingly limited. For reference purposes, the combination of the Sunbury balanced disc-valve unit, the control unit, and the Farnboro' indicator has been termed "B.I.C.E.R.A. engine indicating system 1."

As this work approached completion, a paper* was published describing the development in the Department of Mechanical Engineering, University of Witwatersrand, of a modified form of Farnboro' indicator in which the free disc valve is replaced by a thin diaphragm. The moment of pressure balance is indicated by the breaking of contact between a central contact point and the diaphragm. The thin diaphragm is supported at the extreme positions of movement by backing plates, and the contact point is adjusted so that it just makes contact with the diaphragm when this is resting against the backing plate on the side to which the steady pressure is applied.

To avoid pitting of the contact surfaces, a small current is used and the voltage changes produced by the action of the contact breaker are applied to the grid of a thyratron valve controlling the sparking coil. An indicator which embodies the same features has been developed by the Massachusetts Institute of Technology, and is manufactured by the American Instrument Company.† This modification overcomes the two main defects of the Farnboro' indicator—pitting of the contact surfaces and fouling by carbon or lacquer—but introduces other serious difficulties. A description of the action of a balanced diaphragm unit, and indications of the sources of error, are given in an early report by Dickinson and Newell of the Bureau of Standards.‡ It is extremely difficult to arrange a thin clamped diaphragm so that it is truly flat. Even if the diaphragm surfaces are perfect planes before clamping, the process of clamping produces radial compression tending to make the diaphragm bulge, and in this manner a large biasing force may be produced. Even if the diaphragm is clamped initially so that it is flat and exerts no force on the backing plate, and at the same time the contact point is adjusted so that it makes contact with the diaphragm but exerts no force on it, it is unlikely that these conditions will be maintained when the unit is screwed into a cylinder head, and heated. It should be noted that the sparking of calibration lines across the pressure diagram, at a number of known applied

* "An Improved Balanced Pressure Engine Indicator," by C. J. Rallis. *Jl. South African Institution of Engineers*, October, 1948, page 35; and *Mechanical World*, January, 1949, page 7.

† *Bulletin* 2152. American Instrument Company, Incorporated, Silver Spring, Washington, D.C.

‡ "A High-Speed Engine Pressure Indicator of the Balanced Diaphragm Type," by H. C. Dickinson and F. B. Newell. National Advisory Committee for Aeronautics Report No. 107.

pressures, merely calibrates the air piston springs and linkage system, whilst the operation of the contact breaker or its equivalent at the true moment of pressure balance is taken for granted in all such systems. The free disc of the Sunbury unit moves at the true moment of pressure balance because only the gas forces act on it. It is free of the objections to the original Farnboro' unit and the diaphragm type modification.

A further advantage of the use of a balanced disc valve, as opposed to a diaphragm, is that it makes possible the construction of a very small pick-up unit. A suitable disc valve can readily be housed in a pick-up having a stem of external diameter of $\frac{1}{4}$ in. An even smaller size of stem appears practicable. Such units can be accommodated in cylinder heads in which no provision has been made or can be made for a pick-up of normal size. Even where an indicator passage is provided, an advantage is frequently gained, since such passages are often of sufficient length, particularly in high-speed engines, to produce large high-frequency pressure fluctuations by wave action. The methods previously adopted to overcome this difficulty have left the result in considerable doubt. The new pick-up may be inserted into the indicator passage after this has been enlarged if necessary. Such passages are commonly of $\frac{1}{8}$-in. diameter, even in the smallest engines, and the removal of $\frac{1}{16}$ in. from the surrounding wall by drilling to $\frac{1}{4}$ in. diameter is usually practicable. In this manner the total effective passage length can be reduced to $\frac{1}{2}$ in. or less. This is of importance even though, as pointed out earlier, the balanced disc-valve unit cannot respond to the high-frequency pressure changes which occur under some conditions in the cylirder and other parts of the engine. The elimination of the passage eliminates the spurious scatter of points due to wave action in the passage. The stem of the unit may be made as long as necessary.

In view of the difficulty of accommodating either a permanent magnet or an electromagnet of suitable size in the available space, the unit was arranged as a condenser, the capacity of which is changed by movement of the disc. The design is shown in Fig. 11. Fig. 12 shows the simple input circuit which feeds the thyratron control unit. The components of the input circuit are housed in a small fitting which connects the disc-valve unit to the cable leading to the thyratron control unit. The input circuit was fed by a 150-volt high-tension battery. A stabilised supply could readily be embodied in the thyratron control unit for this purpose. With this arrangement the delay periods for various rates of pressure change were measured by the method described for the indicating system 1, with results similar to those shown in Fig. 10 for the Sunbury disc-valve unit. The condenser-type pick-up was found to be somewhat less shock-sensitive and thus more suitable for use in cases where there is serious vibration, since this tends to produce spurious points in the diagram. In view of this, a short and more robust form of condenser-type balanced disc-valve unit was constructed for use in cases where the stem-type unit offers no advantage. The design is shown in Fig. 13. Fig. 14 shows a typical application of the stem-type unit, and Fig. 15 shows the two forms of condenser-type unit side by side, together with the small fitting containing the input circuit.

For reference purposes the combination of either design of condenser-type disc-valve unit, the input circuit, the control unit and the Farnboro' recording unit, has been termed " B.I.C.E.R.A. engine indicating system 2."

System 1 has been in use in the laboratory long enough to show that it is reliable and does combine the accuracy of the Sunbury point-by-point method with the speed of the Farnboro'. System 2, which incorporates the condenser-type disc-valve unit, has been employed successfully for several applications, including one of the type shown in Fig. 14. The unit was discoloured by the heat but continued to operate satisfactorily. It is considered, however, that System 2 has not been fully tried. The condenser-type units may be used, without the input circuit shown in Fig. 12, with the Southern Instruments indicator in place of the condenser-diaphragm-type unit normally employed with the equipment. Point-by-point readings have been taken in this manner with a stem-type unit, but the system, being of secondary interest, has not been developed to spark diagrams. A considerable saving of time can be expected by the use of the new equipment, especially for recording the low-pressure, inlet, cylinder, and exhaust diagrams previously obtained by the point-by-point method. The new equipment will meet the requirements for certain types of work, but there is still much scope for further development.

The new indicators and pick-ups described in this report are protected by patents and patent applications owned by B.I.C.E.R.A. and by Standard Telephones and Cables, Limited, Aldwych, London, W.C.2. The thyratron control unit, and condenser-type disc-valve units, with connector incorporating the input circuit, are being manufactured by Standard Telephones and Cables, Limited.

DREDGER FOR THE THAMES CONSERVANCY.

ROWHEDGE IRONWORKS COMPANY, LIMITED, ROWHEDGE, ESSEX.

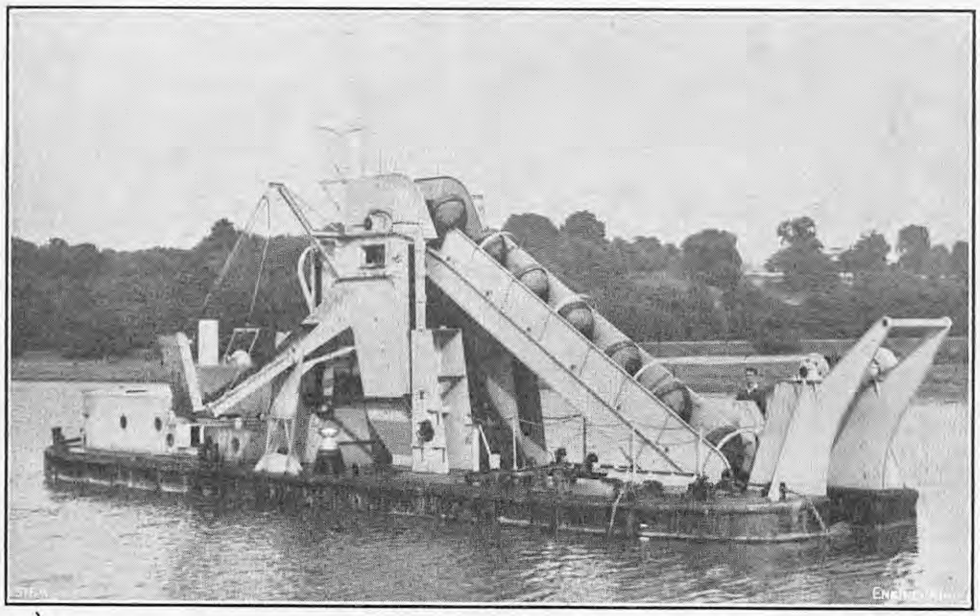


FIG. 1. DREDGER WITH LADDER RAISED.

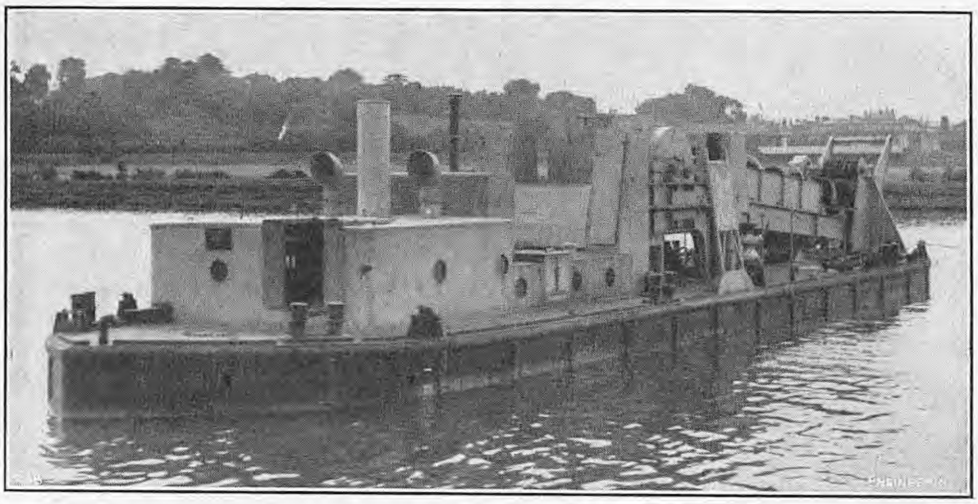


FIG. 2. SUPERSTRUCTURE LOWERED TO PASS UNDER BRIDGES.

DREDGER FOR THE THAMES CONSERVANCY.

A DREDGER of somewhat unusual design, recently constructed by the Rowhedge Ironworks Company, Limited, of Rowhedge, near Colchester, to the order of the Thames Conservancy, is illustrated in Figs. 1 and 2, herewith, Figs. 3 and 4 on the opposite page, and Figs. 5 to 8, on page 814. Fig. 1 shows the vessel in normal working order. The unusual feature, to be seen in Fig. 2, is that, as the dredger is intended for service on the upper Thames, where there are occasional low bridges to be passed, the superstructure supporting the top end of the bucket ladder can be lowered into the well, thus reducing the headroom required to only 11 ft. above the water-line.

The vessel has an overall length of 70 ft. 6 in., a moulded breadth of 16 ft., a moulded depth of 5 ft., and a maximum draught of 3 ft. 6 in. in fresh water. The hull is ship-shaped at the forward end and is slightly shaped also at the after end, as can be seen from the plan reproduced in Fig. 4. It is of steel, with transverse framing, and is subdivided into a forepeak, machinery space, crew's quarters, and buoyancy spaces on each side of the open-ended well. Riveting is used throughout the hull. The dredger can cut its own flotation, and can dredge to a maximum depth of 15 ft., with an output of 129 cubic yards per hour. The bucket ladder is constructed of two rolled-steel joists, with the lower ends slotted to carry split cast-iron bearings for the bottom tumbler shaft. The top end has heavy mild-steel bosses, bushed with gunmetal, to take the ladder hinge-pin. The bottom-end bearings, by adjustment of which the chain of buckets is maintained at the correct tension, are fitted with hardwood packing on each side of the bearings, the whole being secured by mild-steel keeps, held by stainless-steel studs and steel nuts. The rollers which support the bucket chain are of cast iron and flanged, and are mounted on mild-steel shafts carried in bearings bushed with gunmetal. The top and bottom tumblers are of cast steel, the top tumbler being square in section and the bottom tumbler hexagonal. Both have horn pieces cast on them to engage with the bucket chain, the corners of the working faces being fitted with renewable wearing pieces of manganese steel.

There are 21 buckets, each with a capacity of 2·9 cub. ft. when filled flush. They consist of a mild-steel casting forming the back, to which is attached a body of mild-steel plate with a renewable lip of manganese steel. The body plates are drilled with holes to allow water to drain out as the bucket mounts the ladder. The buckets are designed to be interchangeable with those of an older dredger, to reduce the number of spares necessary. Buckets and links are fitted with manganese-steel pins, working in bushes which also are of manganese steel. On passing over the top tumbler, the buckets discharge into a hopper, formed in the superstructure, in which is a hinged plate to divert the spoil into one or the other of the two shoots, one on each side of the dredger. The diverting plate is operated by a hand lever. The shoots are constructed with a hinge, at approximately mid-length, so that the discharge can be distributed to some extent across the hold of the barge which receives the spoil; when the outer section of the shoot is raised, the spoil falls into the nearer side of the barge, and if it is lowered the discharge is directed to the far side. A general view of the bucket ladder is given in Fig. 5, on page 814; and Fig. 6, on the same page, looking down the ladder from the top of the superstructure, shows the gallows and chain hoist by means of which the bottom end of the ladder is raised or lowered. The chains are attached to cast-steel eyeplates on the ladder. The

DREDGER FOR THE THAMES CONSERVANCY.

ROWHEDGE IRONWORKS COMPANY, LIMITED, ROWHEDGE, ESSEX.

Fig. 3

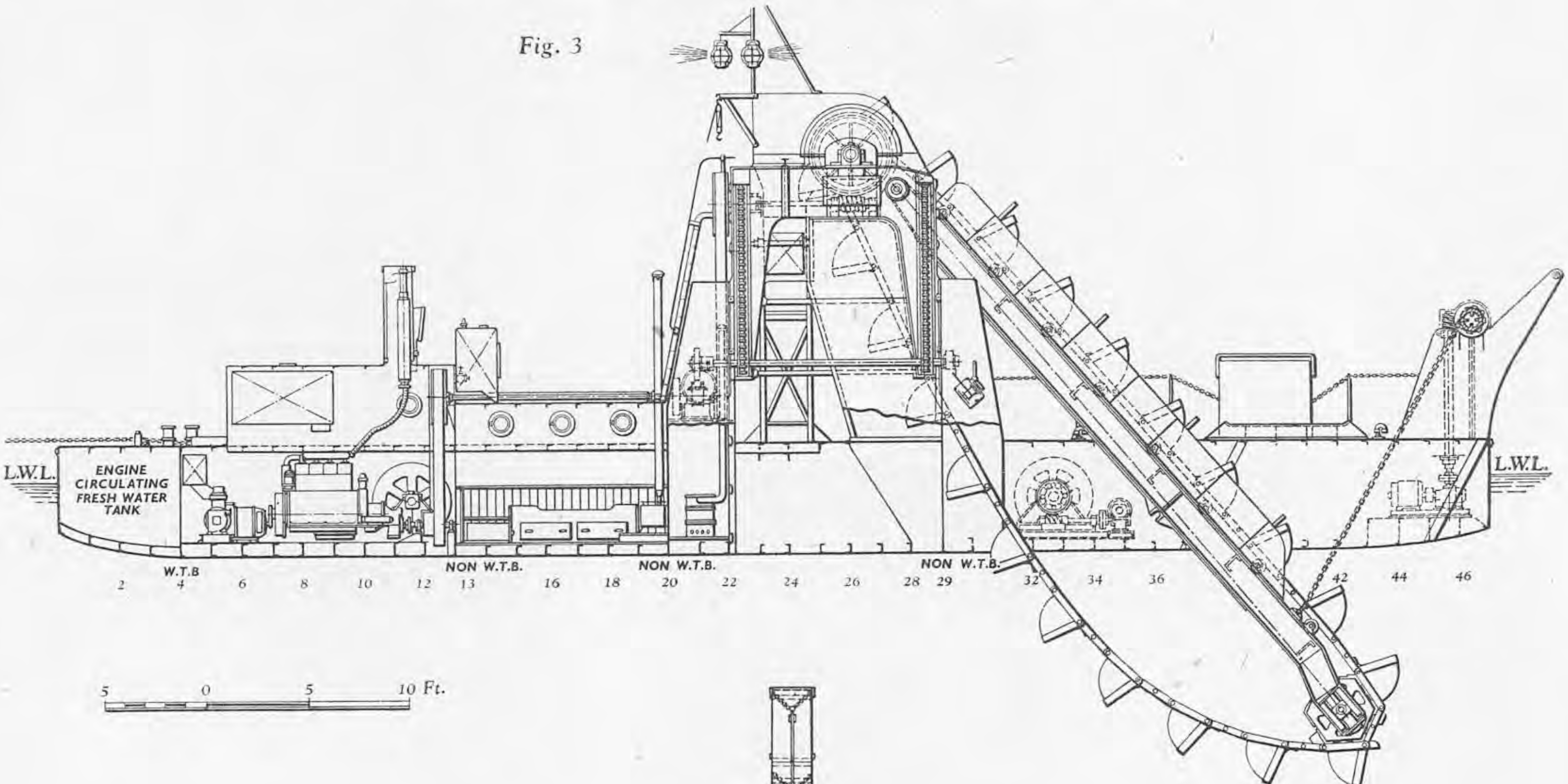
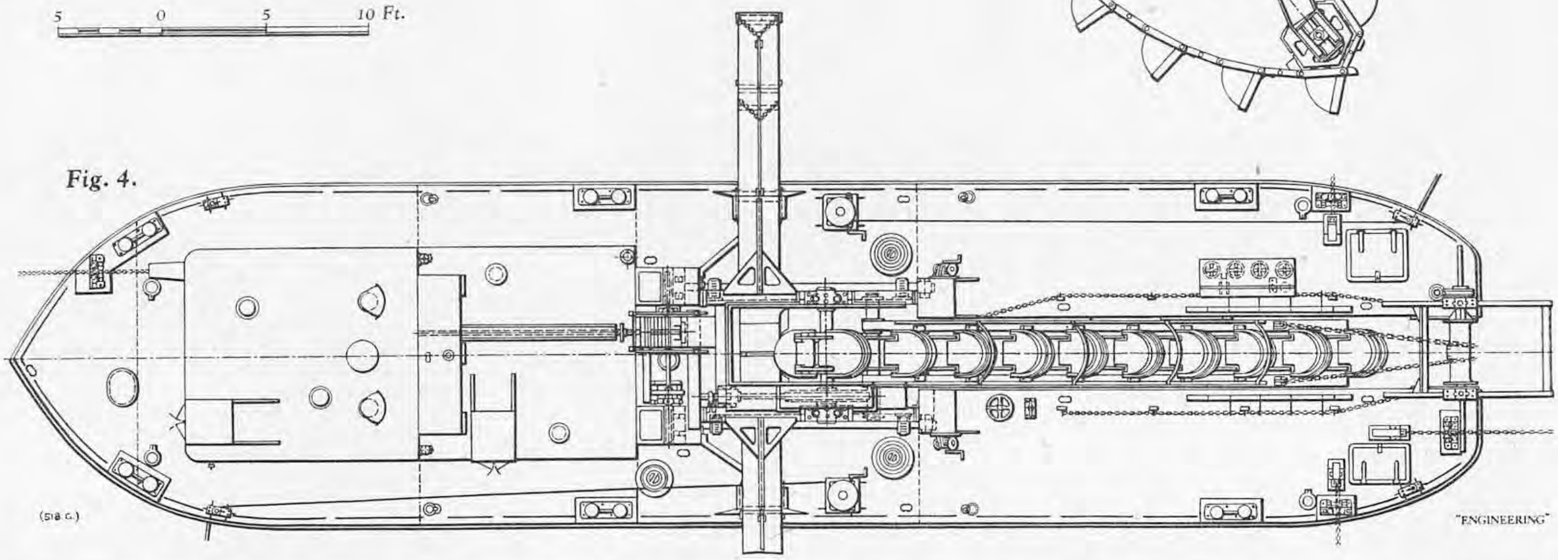


Fig. 4.



depth to which the buckets are working is shown on a scale marked along the deck at the side of the well, the intersection of the underside of the ladder girder with the deck edge indicating the depth on the scale. There is also a depth indicator on the control panel for the warping winches. The drive to the chain winch for raising and lowering the ladder is from an electric motor through a worm gear below the deck and a second worm gear on the shaft of the chain drum.

The bucket chain is driven by a four-cylinder marine-type Diesel engine supplied by Messrs. Russell, Newbery and Company, Limited; it is their size EM4, developing 53 b.h.p. at 800 r.p.m. The engine is cooled by fresh water in a closed circuit; a make-up supply of fresh water is carried in the forepeak. The drive to the bucket chain is through a 2 : 1 reducing gear and thence by belt and countershaft to a worm reduction gear on the top tumbler shaft (Fig. 7, page 814), which makes 10 revolutions a minute, corresponding to a speed of 20 buckets a minute.

There are four electric warping winches, two for hauling ahead or astern and two for quartering; all are fitted below the deck, and are controlled from the cabinet to be seen beside the bucket ladder in Fig. 6, on page 814. The main engine can be controlled from the same cabinet. Each winch has a cast-iron chain drum, on which the chain is stowed, and is driven by a reversible electric motor through two sets of worm reduction gearing. Their positions in the hull can be seen in the arrangement drawings, Figs. 3 and 4. The winches haul in and pay out at a speed of 10 ft. per minute. The after winch has a clutch to release the drum from the driving mechanism, so that the chain can be allowed to run out freely.

The lowering of the superstructure is effected by the main engine, driving through a system of racks and pinions; one of the racks can be seen in Fig. 8, on page 814. To lower the structure into the well, the side shoots and other portable fittings are dismounted, and a belt is fitted on pulleys provided to connect the main drive to the pinion shaft. The superstructure can then be lowered in about ten minutes.

The electric current for the winches is supplied at 220 volts by an $8\frac{1}{2}$-kW direct-current generator, driven by belt from the main engine. There is an electric starter for the main engine, this being operated from batteries in the engine room, which also feed the 24-volt lighting system. The electrical equipment was supplied by the Central Electrical Company (Colchester), Limited. The 200-gallon fuel tank for the main engine, which is fitted in the engine room, can be replenished by gravity from a 300-gallon tank mounted on the cabin casing. A Petter AV-type single-cylinder Diesel engine, developing 3 brake horse-power at 1,000 r.p.m. is directly coupled to a Megator pump, with a capacity of 1,000 gallons an hour, for bilge and wash-deck services. The dredger is worked by a crew of three, who are accommodated in a cabin abaft the engine room, fitted with three bunks and a cooking range.

POTATO HARVESTER COMPETITION.—Some further information has been received from the Royal Agricultural Society about their projected potato-harvester competition, due to be held during the next harvest in two parts of the country, namely, the West Midlands and Cambridgeshire. To be eligible for acceptance, entries must consist of a machine, or groups of machines, undertaking the full sequence of operations from lifting the potatoes from the ridge to depositing them directly into bags or a bulk container on the machine or to a vehicle travelling with the outfit. The competition is open to both British and foreign machines; of the 25 entries finally accepted, four are foreign, two being from Sweden, one from Denmark and one from Holland. The British entries embrace almost all production machines and include an interesting selection of new and experimental entries; some of which have been developed in farm workshops. Several mechanisms for soil separation are included, but major interest will be in those devices designed to effect mechanical separation of stones from the crop. The trials will be of an extensive nature and, in addition to output per man hour, marks will be awarded on such aspects as crop damage, cleanness of sample, convenience of operation, accessibility and soundness of design and construction.

INDEX OF TECHNICAL ARTICLES.—In collaboration with the Norwegian Industries Development Association, the Cleaver-Hume Press, Limited, 485, Oxford-street, London, W.1, are publishing an index, with brief summaries in English, of technical articles published throughout the world. The Cleaver-Hume Index covers 700 technical journals, and will be issued monthly, in three sections; the annual subscription to each section is 3 guineas. Section A will cover the mining, quarrying and extractive industries, metallurgy, foundries, materials handling, welding, workshop technology, heat and power, machine-tool manufacture, prime movers, and electrical technology. Section B deals with optics and photography, timber technology, paper technology, building, heating, ventilation and sanitation, transportation, shipbuilding, railways, roads, and air, packaging, and industrial organisation and patents. The chemical, food, paint, textile and plastic industries are covered in Section C. A Photostat copying service and technical-translation service are also available.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

FUEL SURVEYS.—Sir Patrick Dollan, chairman of the Scottish Fuel Efficiency Committee, has announced that the Scottish Fuel Advisory Council have now completed 33 surveys of large plants in Scotland with mobile testing units, and that there have also been 21 minor surveys. These visits have all resulted in the saving of coal, in some cases by as much as 25 per cent.

BALVICAR SLATE QUARRIES.—The slate quarries at Balvicar, Island of Seil, near Oban, which closed down two years ago, have been reopened to meet the rising demand for West Highland slates in housing schemes. The Balvicar quarries were the first to resume in Scotland after the war, when the industry was reorganised by Scottish Slate Industries, Ltd., the merger company now controlling most of the Scottish slate quarries.

WESTERN WHARF, DUNDEE HARBOUR.—The Minister of Transport has authorised Dundee Harbour Trustees to carry out the reconstruction of the Western Wharf at a cost of 390,000*l*. Permission has been given for the work to begin on February 1.

MACHINE-TOOL FACTORY FOR N.W. SCOTLAND.—A factory to make machine tools is to be established at Inverasdale, a crofting community on the shores of Loch Ewe, in Wester Ross, a non-development area. Mr. H. A. Rendel Govan, planning consultant for the mainland of Ross and Cromarty, welcomed the decision of the County Council to support the venture. The scheme, he said, would compete with the industries in the development areas, but it might be the beginning of something much bigger.

CARGO HANDLED AT GRANGEMOUTH.—Trade handled at Grangemouth Dock in 1951 has exceeded 3,250,000 tons—the highest figure in 21 years—making the port second only to Glasgow among Scottish docks in volume of trade. Oil exports from the new Anglo-Iranian refinery at Grangemouth have helped to increase the total, but imports of timber, minerals, and general cargoes have all shown increases.

NEW PLANT FOR COTTON MILL.—Crofthead Mill, Neilston, is to be modernised by the English Sewing Cotton Company at a net cost of 300,000*l*., including 136,408*l*. for machinery. Production is to be increased by about 50 per cent. The machinery is being provided by Platt Bros. & Co., Ltd., of Oldham, and includes 88 new doubling machines with ancillary equipment. The total capacity of the new plant will be 31,768 spindles.

EXTENSION TO RUNWAY AT PRESTWICK.—A proposal to extend the main runway at Prestwick Airport, and to divert the main Ayr-Kilmarnock-Glasgow road bordering the present runway by means of a tunnel under the runway extension, was accepted on December 21 by Ayr County Council. The main runway was recently extended by some 300 ft., giving a distance of som 7,000 ft. for aircraft landing and taking off.

CLEVELAND AND THE NORTHERN COUNTIES.

OUTLOOK IN IRON AND STEEL INDUSTRY.—Obstacles to transactions in North of England iron and steel products are increasingly difficult to overcome and the volume of business passing is extremely light. Outputs are interrupted by shortages of iron and steel scrap and other requisite commodities. Most of the output of the Tees-side blast-furnaces is moving into prompt use at the melting shops and very little Middlesbrough-made pig iron is available for other purposes. Among the few recent welcome developments in a generally unsatisfactory situation, however, is the fact that the mild weather has facilitated finished-steel clearances. There is an absence of complaints of rail transport delays, which are usually prevalent at this season of the year.

SHIPBUILDING ON THE TEES.—The Furness Shipbuilding Co., Ltd., have sufficient orders on their books to keep their shipbuilding yard at Haverton Hill-on-Tees fully occupied for the next seven years. They have recently booked an order for five additional tankers, the largest of which is a steamer of 32,000 tons deadweight capacity. Her propelling machinery will consist of double-reduction geared turbines. The second vessel is another turbine steamer and will have a deadweight capacity of 24,750 tons. The third turbine-driven tanker is also of 24,750 tons, while the fourth and fifth vessels will be oil-tank motorships of 16,300 tons deadweight capacity. It is announced that the Furness Company have, at present, 40 tankers on their books and in various stages of construction.

OVERHAUL OF H.M.S. MAURITIUS.—The Fiji class cruiser H.M.S. Mauritius, of 8,000 tons, is to dock in the Tyne towards the end of January for an overhaul and refit. She was built by Swan, Hunter, and Wigham Richardson, Ltd., Wallsend, and was completed in December, 1940. Last June she was despatched to Abadan and was responsible for bringing away some 300 British members of the staff of the Anglo-Iranian Oil Company and their families.

LANCASHIRE AND SOUTH YORKSHIRE.

HIGHER COSTS IN THE STEEL INDUSTRY.—Higher railway freights and dearer fuel will affect Sheffield steel seriously in the New Year. Last year, the steel industry of Sheffield and district used 2,718,800 tons of material, other than fuel, to make 2,218,300 tons of steel. Some of the material used was scrap arising in Sheffield works, but a large proportion had to be brought in by rail. In addition, the Sheffield steel trades used 1,270,000 tons of coal, the price of which is expected to rise between 1*s*. and 3*s*. 6*d*. per ton, following the extra freight charges. Metallurgical coke to the extent of 228,000 tons was used last year and this will be much dearer in the New Year.

SCIENCE GRADUATES FOR INDUSTRY.—The annual report of Sheffield University states that openings in industry and commerce continue to increase in number, but the competition for them remains very strong. There is some reluctance on the part of candidates to consider openings overseas, especially in the Middle and Far East. The demand for the services of graduates in science, engineering and other branches of technology has been steadily maintained, particularly in chemistry and mechanical engineering. The number of honours graduates in science who become teachers is stated to be very small, as posts in industry are more attractive.

ANXIETY REGARDING STEEL SUPPLIES.—Mr. E. Ransom Harrison, chairman of Walter Spencer & Co., Ltd., steelmakers, Sheffield, stated at the firm's annual meeting that nationalisation of steel, so far as it has gone, was seriously affecting the supply of blooms and billets for the press and forging shops, and the directors were very anxious as to future supplies.

WIRE ROD SHORTAGE.—The 350 employees of the ropery department of British Ropes, Ltd., at Doncaster, have been laid off for ten days at Christmas because of a shortage of wire rods. Some other personnel in the wire mill were also affected. The firm have made a mass registration of affected employees with the employment exchange.

MINING RECRUITS.—Young men are turning more to coal mining for employment in the East Midlands Division of the Coal Board, and manpower in the division increased by 1,750 during 50 weeks of 1951, according to Mr. F. Bingham, the divisional chairman. Recruitment included over 2,000 under the age of 18.

COAL HAULAGE BY ROAD.—A big scheme for the haulage of coal by road, to offset the shortage of railway wagons at colliery screens, is in operation. Long-distance haulage of coal by road from the Yorkshire coalfield has been increased from 90,000 tons to 130,000 tons a week. Coal from South Yorkshire pits has been sent by road as far as Gloucester and across the Pennines to Lancashire.

REASONS FOR WAGON SHORTAGE.—Mr. Duncan Bailey, the chairman of Charles Roberts & Co., Ltd., builders of railway wagons, has stated that the large scrapping policy under nationalisation resulted in probably some 200,000 of the older railway wagons being scrapped. So long as they could be replaced with new 16-ton steel wagons, that was a sound policy; but, for various reasons, the supply of new wagons had not kept pace with the scrapping policy, even though a modern 16-ton wagon will do the work of at least two of the old wagons. Under private enterprise there were some 100,000 wagons known as " the buffer fleet " which, as trade fluctuated, were brought into service or laid up. There must always be a certain number of wagons in reserve to meet peak loads. Only after months of delay had the idea been adopted of upgrading the 14-tonner to 16 tons load.

THE MIDLANDS.

MIDLAND INDUSTRY IN 1951.—The year now ending has been a difficult one for Midland industry. At the beginning of the year it appeared that the major problems were to be shortages of materials and labour, and this has proved to be the case. Shortage of labour has been acute throughout the West Midlands, and at the time of writing there are about 50,000 vacancies on the books of local employment exchanges. There have been many suggestions during the past twelve months for improving matters in this direction. The relatively small number of unemployed in the area is not nearly sufficient to meet current needs, even supposing that all those not in employment were suitable for the vacancies. Some foreigners and displaced persons have moved into the Midlands, but the numbers have been too small to have any great effect. Transfer on a larger scale has proved impossible because of the shortage of housing. Another possible source of labour which is being put forward at the present time is in industries which have concealed unemployment. It is a fact that some firms, suffering from shortage of raw materials, have been reluctant to discharge employees because they fear that, should the materials position improve, they would not be able to get them back.

CANAL TRANSPORT.—The efforts of the Docks and Inland Waterways Executive to improve canal transport facilities to and from the Midlands have been hampered to some extent by a shortage of the kind of labour peculiar to canal work. For many years, men have tended to leave the canals and take employment where they could remain in one spot. A new departure by the City of Birmingham Education Committee may help to solve the problem: they have opened a hostel at Erdington, Birmingham, for the children of boatmen operating over long distances.

ELECTRICITY SUPPLIES.—Mr. H. J. Gibson, chief commercial officer of the Midlands Electricity Board, has pointed out that no power cuts had been made in the Board's area of supply since October 1. He is optimistic that, if present economies are maintained, here may be no need for serious power cuts this winter —the first time for five years.

GASWORKS EXTENSIONS.—The second annual report of the West Midlands Gas Board states that proposed extensions to plant in the Midlands area would involve the consumption of an extra million tons of coal a year. The developments include the provision of new plant at Wolverhampton and Bilston. Extensions to existing undertakings are proceeding at Walsall and Swan Village (West Bromwich); when finished, they will enable the Board to close the gasworks at Oldbury, West Bromwich, Lichfield and Tamworth.

SOUTH-WEST ENGLAND AND SOUTH WALES.

TRAFFIC AT SOUTH WALES PORTS.—Trade passing through the South Wales ports in the first eleven months of this year showed an increase of more than 1,672,000 tons over the corresponding period of last year. This was in spite of a decline from 4,479,973 tons to 2,757,673 tons in exports of coal to foreign destinations. Almost half of the total trade of 18,835,177 tons was handled at Swansea, where a feature has been the substantial growth of the oil trade.

DEVELOPMENT PLAN FOR COUNTY OF GLAMORGAN.—A development plan for the central area of Glamorgan, covering the next 20 years, which was approved by the County Planning Committee at Cardiff on December 18, estimates the amount of building and engineering work to be undertaken by central and local government authorities and other sources at approximately 100,000,000*l*. A list (possibly incomplete) of proposed works by Government departments during the first five years of that period forecasts an expenditure of 12,655,000*l*., including 8,000,000*l*. for a new coast power station for the British Electricity Authority, 2,000,000*l*. for National Coal Board developments in the area, 1,000,000*l*. for extensions to the Port Talbot works of the Steel Company of Wales, and schemes for 35 new roads and road improvements, to cost about 6,000,000*l*. The central area extends from Llanharan, 30 miles west to the boundaries of Swansea, and it is likely to become the busiest part of the county in the future. The development of new industries in the area should attract over 41,000 people by 1971, according to the county surveyor and planning officer, Mr. E. John Powell.

RECORD OUTPUT AT EBBW VALE.—The strip mill at Ebbw Vale achieved a record output of more than 16,000 tons in a 17-shift week which ended on December 15. The previous record, set up a year ago, was just below 15,000 tons.

UNDERGROUND TELEPHONY IN SOUTH WALES COALFIELD.—As a result of recent developments, it is now possible for an administrator in the Cardiff office of the South Western Divisional Coal Board to speak by telephone to an official underground at any colliery in the South Wales coalfield. The new service was inaugurated on December 19 by the chairman of the Divisional Board, Mr. G. E. Aeron-Thomas, who spoke from Cardiff to Mr. Ivor Davies, under-manager of the Lady Windsor Colliery, near Pontypridd, who was a quarter of a mile below ground.

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.

INCORPORATED PLANT ENGINEERS.—*South Wales Branch:* Tuesday, January 1, 7.15 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Film on "Hard Surfacing with Stellite." *Southampton Branch:* Wednesday, January 2, 7.30 p.m., Polygon Hotel, Southampton. Discussion on "The Factories Act." *Peterborough Branch:* Thursday, January 3, 7.30 p.m., Offices of the Eastern Gas Board, Church-street, Peterborough. "Power Distribution," by Mr. G. J. Richardson. *Edinburgh Branch:* Tuesday, January 8, 7 p.m., 25, Charlotte-square, Edinburgh. "Organisation of Scientific Research in Great Britain," by Dr. H. Buckley. *East Lancashire Branch:* Tuesday, January 8, 7.15 p.m., Engineers' Club, Manchester. "Secondary Air and Its Application," by Mr. H. Hetherington. *East Midlands Branch:* Wednesday, January 9, 7 p.m., Welbeck Hotel, Nottingham. "Building a Passenger Liner," by Mr. J. Melville. *Kent Branch:* Thursday, January 10, 7 p.m., Queen's Head Hotel, Maidstone. "Automatic Combustion Control as Applicable to Industrial-Type Boilers," by Mr. S. J. Clifton.

INSTITUTION OF PRODUCTION ENGINEERS.—*Reading Section:* Tuesday, January 1, 7.15 p.m., Great Western Hotel, Reading. "Industrial Design and the Engineer," by Mr. K. L. Brookfield. *Wolverhampton Section:* Wednesday, January 2, 6.30 p.m., Star and Garter Hotel, Wolverhampton. Film on "Polished Plate Glass and 'Armourplate' Glass." *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. *London Section:* Thursday, January 3, 7 p.m., Old Ship Hotel, Brighton. "Improvements and Their Hindrances," by Mr. C. R. Whitaker. *Halifax Section:* Monday, January 7, 7.15 p.m., George Hotel, Huddersfield. "Steam Turbine Manufacture," by Mr. A. C. Annis.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*East Midlands Branch:* Wednesday, January 2, 6.30 p.m., Victoria Station Hotel, Nottingham. "Special Applications of Air Conditioning," by Dr. B. Edgington. *North-East Coast Branch:* Tuesday, January 8, 6.30 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "School Heating," by Dr. J. C. Weston. *Institution:* Wednesday, January 9, 6 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Fibrous Filters for Fine-Particle Filtration," by Dr. D. J. Thomas.

INSTITUTION OF MECHANICAL ENGINEERS.—*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. *North-Eastern Branch:* Monday, January 7, 6 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. Annual Meeting. "The Measurement and Interpretation of Machinery Noise, with Special Reference to Oil Engines," by Mr. C. H. Bradbury. *South Wales Branch:* Tuesday, January 8, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Thomas Hawksley Lecture on "Some Fuel and Power Projects," by Dr. H. Roxbee Cox. *Scottish Branch:* Thursday, January 10, 7.30 p.m., Royal Technical College, Glasgow. "Steel Castings and the Engineer," by Mr. J. F. B. Jackson. AUTOMOBILE DIVISION.—*Birmingham Centre:* Tuesday, January 1, 7.15 p.m., Craven Arms Hotel, Coventry. "Shock Absorbers," by Mr. J. W. Kinchin and Mr. C. R. Stock. *Western Centre:* Thursday, January 3, 6.45 p.m., Royal Hotel, Bristol. Informal Discussion.

JUNIOR INSTITUTION OF ENGINEERS.—*Midland Section:* Wednesday, January 2, 7 p.m., James Watt Memorial Institute, Birmingham. "The Manufacture of Coins," by Mr. G. H. Thompson. *Institution:* Friday, January 4, 6.30 p.m., 39, Victoria-street, S.W.1. Film on "Rocket Flight," introduced by Mr. S. G. Clark. *North-Western Section:* Monday, January 7, 7.30 p.m., 16, St. Mary's Parsonage, Manchester. Chairman's Address, by Mr. A. Eaton.

INSTITUTION OF ENGINEERING INSPECTION.—*Birmingham Branch:* Wednesday, January 2, 7.30 p.m., Chamber of Commerce, 95, New-street, Birmingham. "Petroleum Products," by Mr. K. H. Holman. *Institution:* Thursday, January 3, 6 p.m., Royal Society of Arts, John Adam-street, W.C.2. "Quantity Production of Geared Instruments for Time and Linear Measurements," by Mr. T. G. Mercer.

INSTITUTE OF METALS.—Thursday, January 3, 2.30 p.m., The University, Birmingham. Discussion on "Tool and Die Materials for the Hot-Working of Non-Ferrous Metals and Alloys." *London Local Section:* Thursday, January 3, 7 p.m., 4, Grosvenor-gardens, Westminster, S.W.1. "Research on the Working of Metals," by Mr. W. C. F. Hessenberg.

LEEDS METALLURGICAL SOCIETY.—Thursday, January 3, 7 p.m., The University, Leeds. "The Platinum Metals: Their Properties and Uses," by Dr. J. C. Chaston.

INSTITUTION OF WORKS MANAGERS.—*Tees-side Branch:* Thursday, January 3, 7.30 p.m., Vane Arms Hotel, Stockton. "The Profession of Management," by Mr. A. M. Hudson Davies. *Merseyside Branch:* Tuesday, January 8, 6.30 p.m., Adelphi Hotel, Liverpool. "Management Practice in the United States," by Mr. E. Packer. *Birmingham Branch:* Tuesday, January 8, 7 p.m., Grand Hotel, Birmingham. "Production Economy," by Mr. T. A. Yapp.

ILLUMINATING ENGINEERING SOCIETY.—*Birmingham Centre:* Friday, January 4, 6 p.m., Imperial Hotel, Birmingham. Joint Meeting with INSTITUTE OF ROAD TRANSPORT ENGINEERS. "Modern Transport Lighting," by Mr. W. E. J. Drake. *Bath and Bristol Centre:* Friday, January 4, 7 p.m., Offices of the South Western Electricity Board, Old Bridge, Bath. "Neon Lighting," by Mr. C. Higgins. *London:* Tuesday, January 8, 6 p.m., Royal Society of Arts, John Adam-street, W.C.2. "Lenses for Lighthouses," by Mr. W. M. Hampton.

INSTITUTION OF ELECTRICAL ENGINEERS.—*South Midland Centre:* Monday, January 7, 6 p.m., James Watt Memorial Institute, Birmingham. "Protection of Electrical Power Systems: A Critical Review of Present-Day Practice and Recent Progress," by Mr. H. Leyburn and Mr. C. H. W. Lackey. *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. *Measurements and Radio Sections:* Tuesday, January 8, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. (i) "Two Electronic Resistance or Conductance Meters," by Dr. L. B. Turner. (ii) "A Bridge for the Measurement of the Dielectric Constants of Gases," by Mr. W. F. Lovering and Mr. L. Wiltshire. *North-Western Centre:* Tuesday, January 8, 6.15 p.m., Engineers' Club, Manchester. "Electricity in Newspaper Printing," by Mr. A. T. Robertson. *North Midland Centre:* Tuesday, January 8, 6.30 p.m., Hotel Metropole, Leeds. (i) "Crystal Diodes," by Mr. R. W. Douglas and Dr. E. G. James. (ii) "Crystal Triodes," by Mr. T. R. Scott. *Southern Centre:* Wednesday, January 9, 6.30 p.m., Polygon Hotel, Southampton. "Domestic Electrical Installations: Some Safety Aspects," by Mr. H. W. Swann. *Scottish Centre:* Wednesday, January 9, 7 p.m., Heriot-Watt College, Edinburgh. "Transient Theory of Synchronous Generators Connected to Power Stations," by Mr. B. Adkins.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Sheffield Branch:* Monday, January 7, 7.30 p.m., College of Technology, Pond-street, Sheffield. "Synthetic Resins as Foundry Sand Binders," by Mr. P. G. Pentz. *Burnley Section:* Tuesday, January 8, 7.30 p.m., Grammar School, Blackburn-road, Accrington. "Phosphor Bronze," by Mr. E. Jackson. *Lincolnshire Branch:* Thursday, January 10, 7.15 p.m., Technical College, Lincoln. "Production of Turbine Castings," by Mr. N. Charlton. *Middlesbrough Branch:* Friday, January 11, 7.30 p.m., at Messrs. Head, Wrightson and Co., Ltd., Teesdale Iron Works, Thornaby-on-Tees. "Process Planning in the Steel Foundry Industry," by Mr. S. L. Finch.

INSTITUTION OF CHEMICAL ENGINEERS.—Tuesday, January 8, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Froth Flotation Kinetics," by Mr. William Gibb.

INSTITUTE OF PETROLEUM.—Wednesday, January 9, 5.30 p.m., Manson House, 26, Portland-place, W.1. "Some Aspects of Field Operations in Kuwait," by Mr. E. Boaden and Mr. E. C. Masterson.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*North-Eastern Section:* Wednesday, January 9, 6 p.m., Neville Hall, Westgate-road, Newcastle-upon-Tyne. "Test Gear Design," by Mr. A. W. Wray. *London Section:* Wednesday, January 9, 6.30 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. "Crystal Triodes," by Dr. E. G. James and Mr. G. M. Wells.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Northern Counties Branch:* Wednesday, January 9, 6.30 p.m., Cleveland Scientific and Technical Institution, Corporation-road, Middlesbrough. "Reconstruction of Houdon-on-Tyne Gas Works," by Mr. W. R. Garrett.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*East Midlands Centre:* Wednesday, January 9, 7.30 p.m., Mechanics Institute, Nottingham. "Use of Aluminium for Road-Vehicle Bodies," by Mr. R. Esmonde.

INSTITUTE OF FUEL.—*North-Western Section:* Thursday, January 10, 2.30 p.m., Radiant House, Bold-street, Liverpool. "Progress in Domestic Heating Research," by Dr. A. C. Monkhouse.

INSTITUTION OF CIVIL ENGINEERS.—*Midlands Association:* Thursday, January 10, 6 p.m., James Watt Memorial Institute, Birmingham. "Sewage Purification," by Mr. David M. Watson.

PERSONAL.

MR. KENNETH GORDON, C.B.E., M.C., has been appointed to the board of Head Wrightson Processes Ltd., Teesdale House, 24-26, Baltic-street, London, E.C.1, as deputy managing director.

MR. T. H. SUMMERSON, chairman and joint managing director of Thomas Summerson & Sons Ltd., Albert Hill Foundry, Darlington, Co. Durham, has been elected chairman of the British Steel Founders' Association.

The directors of BABCOCK AND WILCOX LTD., Babcock House, Farringdon-street, London, E.C.4, announce that MR. H. B. CLARK has asked to be released from the position of secretary as from December 31. He is taking up special duties with the company. MR. L. W. COLE has been appointed secretary to succeed Mr. Clark.

MR. J. K. GILCHRIST, B.Sc. (Glas.), A.R.T.C., A.I.M., has relinquished his position on the research department staff of Babcock and Wilcox Ltd., to take up an appointment as lecturer in metallurgy and chemistry at Paisley Technical College.

MR. G. J. STEDMAN, B.Sc. (Eng.) (Lond.), A.M.I.E.E., A.M.I.Mech.E., has been appointed generation engineer, City of Bulawayo Electricity Department, Southern Rhodesia.

MR. D. J. HOPLEY has been appointed managing director of Oldham and Son (India) Ltd., associate company of Oldham and Son Ltd., manufacturers of storage batteries, Denton, Manchester. He succeeds MR. EDGAR OLDHAM, who is returning to England to continue his work as chief technical officer, overseas control division of the parent company.

COMDR. (E) SAMUEL DICKINSON, O.B.E., R.N., M.I.Mech.E., has been appointed head of the Department of Engineering at the College of Arts, Science and Technology, Ibadan, Nigeria.

MR. ERIC A. SEAL, C.B., formerly Deputy Under-Secretary of State, Foreign Office (German Section), has been appointed Deputy Secretary, Ministry of Works, in succession to SIR NICOLAS DE VILLIERS, K.B.E., who has been appointed Deputy Secretary, Ministry of National Insurance.

E. K. COLE LTD., Southend-on-Sea, Essex, announce that three executives, namely, MR. F. S. ALLEN, M.I.P.E., general works manager, radio division; MR. JOHN CORBISHLEY, chief accountant; and MR. A. W. MARTIN, M.B.E., Assoc.I.E.E., chief engineer, have been elected directors of the company. MR. G. W. GODFREY, general sales manager, radio division; MR. DAVID RADFORD, general manager, Ekco plastics division, and MR. W. M. YORK, in charge of publicity, have been appointed executive directors.

MR. P. D. DOULTON, M.I.Mech.E., has been elected a member of the Executive Committee of the Council of British Manufacturers of Petroleum Equipment.

MR. W. H. PLATT, assistant sales manager (wrought products), The British Aluminium Co., Ltd., Norfolk House, St. James's square, London, S.W.1, is retiring on December 31 after 41 years of service in the sales division of the company. MR. C. F. BATSTONE will combine the functions of principal assistant sales manager with those previously carried out by Mr. Platt.

MR. ROBERT SHEARER, A.M.I.Mech.E., has been appointed mechanical engineer to the Clyde Navigation Trust, Glasgow.

The Council of the Institution of Civil Engineers have awarded the 1951-52 Radley Post-Graduate Studentship of 350*l*. to MR. J. D. GEDDES, a student member of the Institution, to enable him to undertake research in connection with the bearing capacity of driven piles, at King's College, The University of Durham.

MR. C. L. COOKES has been appointed area representative, in the Midlands and South Wales, of E. Boydell & Co., Ltd., Old Trafford, Manchester, 16, manufacturers of Muir-Hill equipment. Mr. Cookes will operate from the firm's Midlands service depot, New Wolverhampton-road, Langley, Birmingham.

The London sales office and warehouse of the rubber and plastic cables division of STANDARD TELEPHONES AND CABLES LTD., Connaught House, Aldwych, W.C.2, has now been transferred to new premises at 48, North Row, Mayfair, W.1. (Telephone: MAYfair 4392.)

BRUCE PEEBLES AND CO., LTD., Edinburgh, 5, have removed their Manchester office to 26, Corporation-street, Manchester, 4. (Telephone: Deansgate 7106.) As heretofore, the manager is MR. H. V. BALM.

THE INSTITUTE OF PACKAGING has vacated its office at 55-61, Moorgate, London, E.C.2, and moved to new quarters at 20-21, Took's Court, Cursitor-street, London, E.C.4. (Telephone: CHAncery 8484.)

R. H. WINDSOR, LTD., Royal London House, 16, Finsbury-square, London, E.C.2, and F. J. STOKES MACHINE CO., Philadelphia, Pennsylvania, U.S.A., have signed an agreement whereby the latter firm will have the exclusive rights to handle, in the United States, Windsor extrusion machines for thermoplastic materials.

DREDGER FOR THE THAMES CONSERVANCY.

ROWHEDGE IRONWORKS COMPANY, LIMITED, ROWHEDGE, ESSEX.

(*For Description, see Page* 810.)

FIG. 5. BUCKET LADDER.

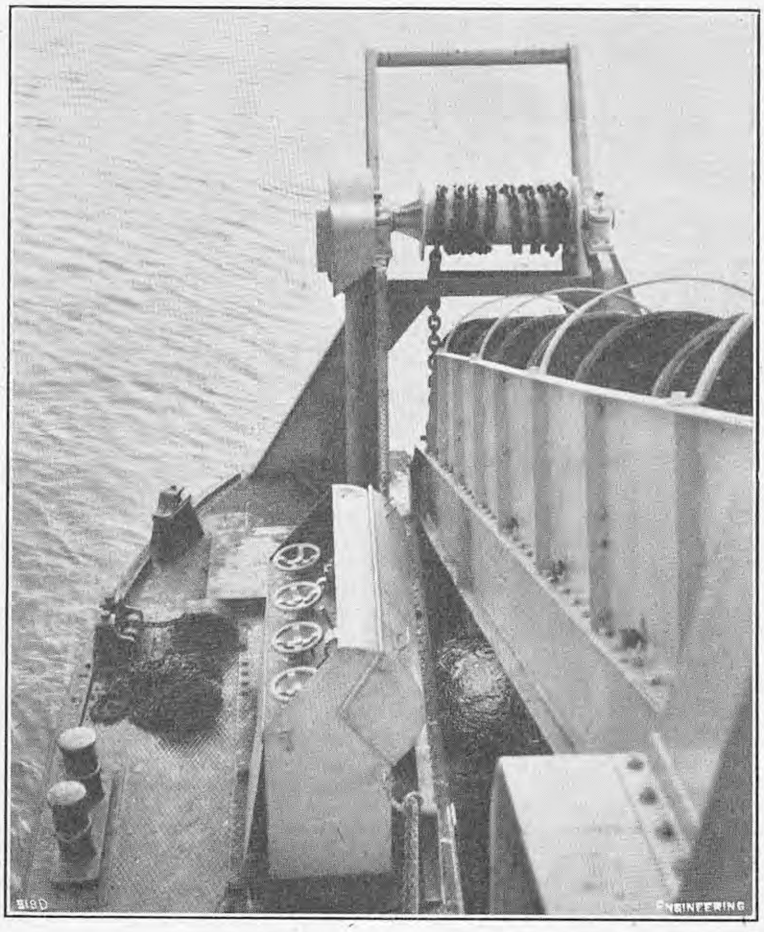


FIG. 6. WINCH CONTROL PANEL.

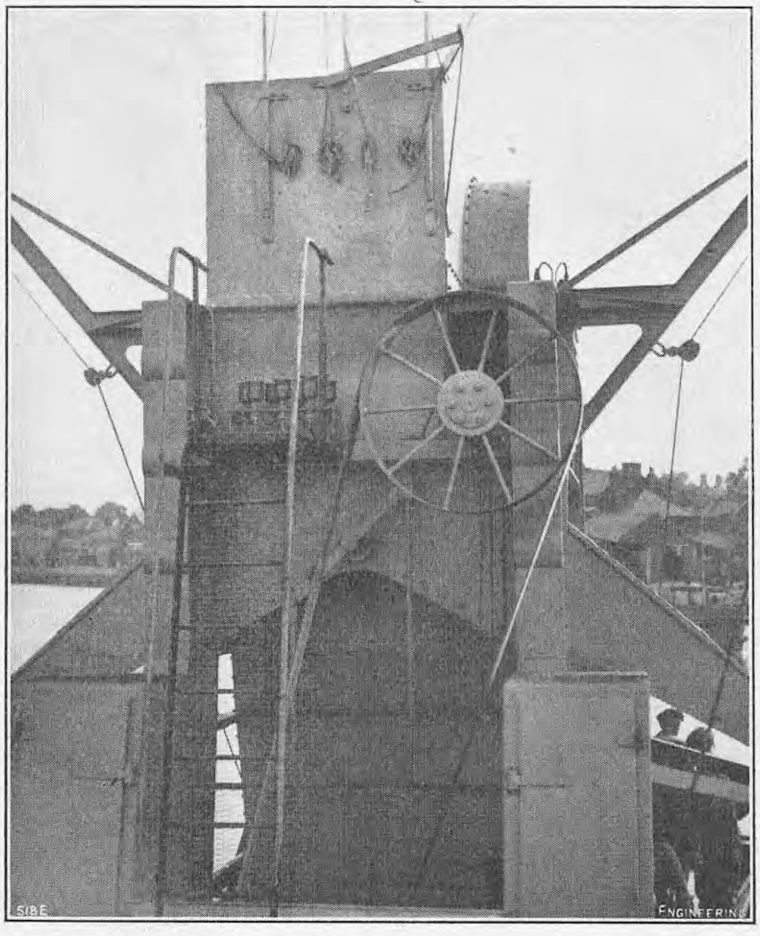


FIG. 7. BELT DRIVE TO TOP TUMBLER SHAFT.

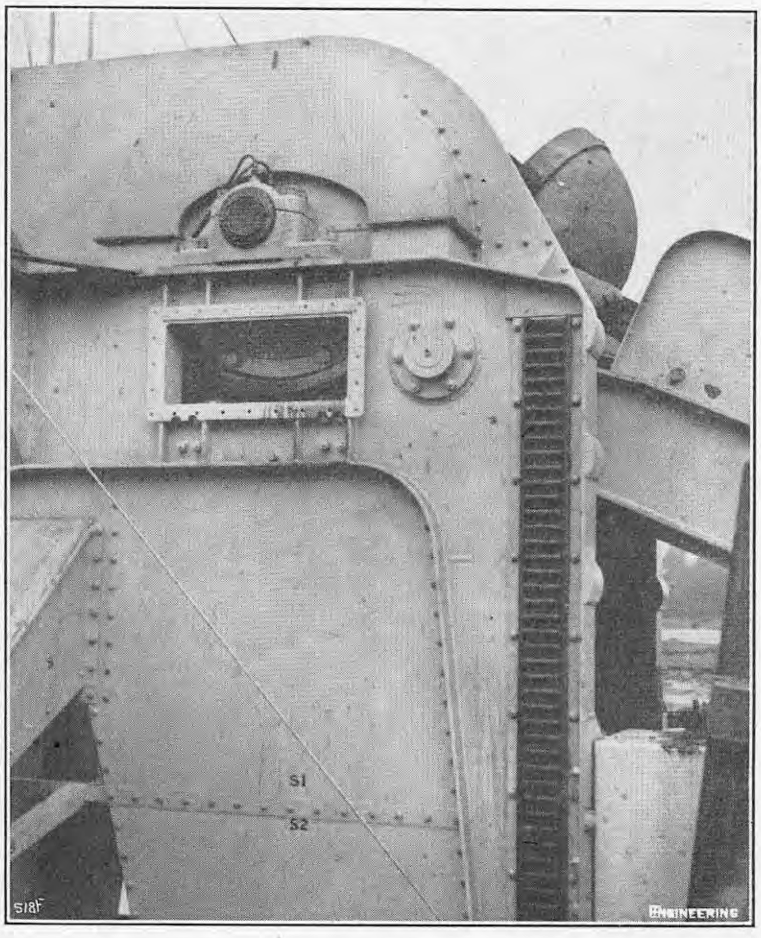


FIG. 8. SUPERSTRUCTURE, WITH LOWERING RACK.

ENGINEERING,

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We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

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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.

CONTENTS.

ENGINEERING

FRIDAY, DECEMBER 28, 1951.

VOL. 172. No. 4483.

RADIO RESEARCH.

THE report of the Radio Research Board for the year 1949 was published seven months ago ; it was reviewed on page 662 of our 171st volume. The corresponding report for 1950* appeared last week and, as before, is accompanied by a detailed account by the Director (Dr. R. L. Smith-Rose) of the work that is being done by this body. Although it is not so late in relation to its period as was its predecessor, the public may still wonder whether so great a delay is unavoidable, and to what extent it detracts from the value of the document. Apparently, the time-lag is wholly due to the publishers.

One essential for the successful conduct of research is somewhere to do the work. It is not surprising, therefore, that the first paragraph of the Report should point out that the fulfilment of the Board's general plan of development still depended largely upon the provision of permanent laboratory and ancillary accommodation in a building which would become the centre of a Radio Research organisation. As it was, much of the year's work had to be carried out in the Radio Division of the National Physical Laboratory, which includes the Radio Research Station at Slough. In addition, some investigations were made at the Telecommunications Research Establishment at Malvern and at University College, Swansea. Such arrangements being far from ideal, negotiations were begun with a view to establishing the station permanently at Ditton Park, in the grounds of the Admiralty Compass Observatory. But, as is somewhat pathetically remarked, there are many factors to be taken into account in dealing with such matters, and many authorities, public and private, to be consulted before there is any assurance that the erection of suitable laboratory buildings will proceed. *Festina lente* may be good advice on occasion, but a thesis might be written on the extent to which it can be applied economically. Pending a decision on the question, it has been necessary to extend the present accommodation at Slough, and to perform some of the work at outlying stations, including one in the Falkland Islands and another at Singapore.

As in former years, a major portion of the work of the Board's staff was the study of radio-wave propagation, though investigations were also carried out on radio noise of various types, on the development of special measuring equipment, and on the properties of certain materials. Research on the properties of the ionosphere were in progress at Slough and at Fraserburgh, as well as at the more remote stations just mentioned, the whole forming part of an international network. Routine measurements were made of the height of reflections as a function of the frequency, and of the absorption occurring at vertical incidence in the ionosphere. Absorption observations at oblique incidence were also made. The data thus obtained were used to prepare regular forecasts of the ionospheric and radio transmission conditions. These forecasts were checked against operational data obtained from commercial and other services and against the continuous recordings of field strength received from distant high-frequency transmitters. Supplementary measurements were made of the direction of arrival of the various ionospheric rays from selected transmitters. The object of these studies was to establish the factors limiting the accuracy of direction finders at high frequencies. They are likely to be of considerable practical value when sufficient data have been accumulated.

In addition, the properties of the ionosphere at low frequencies were examined. For this purpose, equipment designed for the measurement of the phase and amplitude of the ionospheric wave relative to the ground wave was used to study short-distance propagation at 16 kilocycles and 70·8 kilocycles per second. Although a completely satisfactory method of adjusting the orientation of the loop aerial intended to receive the horizontally-polarised component of the ionospheric wave has not yet been found, the use of a method developed by the Cavendish Laboratory, for checking the accuracy of orientation from examination of the phase and amplitude records, proved reasonably satisfactory. Records were thus obtained of the variation with time of the phase difference between the ionospheric wave and the ground wave, and some interesting results were obtained with a Decca Navigation transmitter operating at 70·8 kilocycles.

Bound up with the study of propagation by way of the ionosphere is the level of noise due to atmospherics. A section of the report is therefore devoted to this subject. In this it is recorded that measurements of the interference caused by atmospheric noise at frequencies between 2·5 and 20 megacycles per second were continued at a number of widely separated stations and that a bulletin summarising the results was regularly issued. Efforts in this field were mainly directed towards extending the scope and improving the reliability of the measurements by installing pre-amplifier units associated with the receiving aerials. The measured noise data was compared with values derived from commonly used forecasts of noise levels. The interesting comment is made that, in the preparation of these forecasts, too much weight seems to have been attached to the main thunderstorm centres of the world and too little to the smaller, but more local, centres ; though the effects do not justify any major revision of the forecasts.

It is known that the shape of the impulse constituting an atmospheric depends on the distance of the observing point from the originating lightning flash. The study of the wave forms of atmospherics was therefore renewed to investigate this depen-

* *Radio Research,* 1950. London : H.M. Stationery Office. [Price 1*s*. 9*d*. net.]

dence, and thus to discover whether it provided a practical means of determining the distances of the sources. To do this equipment was built to give photographic records of the wave forms, that is, the variation of the electric field at the aerial as a function of time. This equipment, which is particularly suitable for the routine observation of types of atmospherics and their frequency of occurrence, consisted essentially of two cathode-ray tube displays. The whole of the wave form can be photographed on one of these displays, and the first portion on the other, with an extended time scale. The linear time bases are triggered by the received atmospheric and time-base durations ranging from 1 to 35 milliseconds may be used. Each atmospheric also causes the film to be advanced one frame so that the equipment is ready to record the succeeding values. Such investigations are of interest to the meteorologist. The variation with frequency of the intensity of atmospherics from storms of known location were also studied and the results are being correlated with ionospheric data. On a more practical level, the noise generated in the component items of receiving equipment was measured as part of a general study of the properties of the semi-conductors used as detecting devices and in an attempt to raise the efficiency generally.

Equipment is being developed to measure phase velocity with a view to increasing the accuracy of navigational aids, which is sometimes limited by variations from point to point of the ground-wave propagation velocity. The increase in the use of very short waves for communication, television and other services has led to a study of the factors affecting their propagation, and investigations on measuring techniques have also been continued.

THE SALE OF "DANGEROUS" MACHINERY.

WE have drawn attention from time to time to law cases in which the factory owner has been held liable to pay damages caused by dangerous machinery. We have now the opportunity to consider the position of one who, having made a machine which, if unguarded, would be dangerous, sells it to the owner of a factory. Is he liable to be mulcted in damages if accident ensues ? Mr. Justice Finnemore recently supplied an answer to this question in the case of *Biddle* v. *Truvox Engineering Co., Ltd., Greenwood & Batley, Third Party* (1951) 2 All. E. R. 835. The plaintiff, a workman employed by the defendants, in the ordinary course of his duty was on the platform of a truck, when a lever controlling the platform was pressed by somebody, so that the platform was caused to rise. The plaintiff clutched the nearest thing available to save himself, namely, one of two chains working over chain-wheels. His hand was caught by the wheels and he was injured. He claimed damages for breach of statutory duty, contending that the chains and wheels were a dangerous part of machinery which was not "securely fenced." The defendants contended (in vain, as it turned out) that the chain and wheels were not gearing, and that the cause of the accident was the *novus actus interveniens* in the unauthorised act of the person who pressed the lever. But they did what the rules of procedure entitled them to do, namely, brought in as third parties to the suit the manufacturers who sold them the truck, claiming contribution towards any damages awarded to the plaintiff on the ground that these third parties had been guilty of a breach of statutory duty under S. 17 of the Factory Act in supplying the machine not enclosed.

It is necessary to consider the terms of what that section provides. In the first place, it relates solely to machines intended to be driven by mechanical power. It provides (by *ss.* (1)(*a*)) that every set-screw, bolt or key of any revolving shaft, spindle, wheel or pinion shall be so sunk, encased or otherwise effectively guarded as to prevent danger. This part of the section, however, did not have to be considered in the case under review. The next provision (*ss.* (2)(*b*)) is that "all spur or other toothed or friction gearing, which does not require frequent adjustment while in motion, shall be completely encased, unless it is so situated as to be as safe as it would be if completely encased." Then comes the penal clause which provides (reading it shortly) that any person selling a machine which does not comply with these requirements shall be liable to a fine not exceeding £100. An example of the kind of machine which could come within this provision is the train of gearwheels in the headstock of a gear-cutting lathe. If that lathe were power-driven, those wheels would have to be fenced.

It was admitted in the course of the hearing before Mr. Justice Finnemore that the machine in question had been sold for use in a factory, and that the gearing was not encased. That being so, the factory owner was held liable under *s.* 14 of the Act for not having the machine securely fenced, and also for breach of duty under *s.* 17. Damages amounting to £2,117 were awarded. Whether he had been prosecuted for an offence against the latter section does not appear from the report. The sole question was whether he could pass his liability for damages on to the vendor. This, oddly enough, was a point which has never yet been considered by any Court. It has long been the law (as laid down in the case of *Groves* v. *Lord Wimborne* (1898) 2 Q.B. 402) that, the Factory Act having been passed in favour of workers in factories to compel their employers to do certain things for their protection and benefit, employers who commit breaches of the Act are liable, not merely to a fine, but also to be sued by their employees. The only case which afforded Mr. Justice Finnemore any assistance was *Badham* v. *Lambs, Ltd.* (1945) 2 A. E. R., which related to a motor car sold with a deficient braking system, contrary to the Road Traffic Acts. The purchaser, having been injured in an accident caused by the defective brake, sought to make the vendor liable ; but Mr. Justice du Parcq refused to so decide, holding that there was no indication that Parliament was seeking to protect the purchaser of a car. A specific remedy, namely, a fine for breach of the regulations, having been provided, the purchaser was deprived of any other. Upon this basis, Mr. Justice Finnemore came to the conclusion that the vendor of the truck was not liable to indemnify the factory owner. He said: "It is one thing to say that the occupier of a factory must have his machinery fenced or protected in a certain way, and, if he fails to do so, his employees with whom he is in daily contact—and for whom he is responsible—shall have a right of action against him, and another thing to say that someone who makes and sells a machine shall be under a similar duty to the people employed in somebody else's factory. I have come to the conclusion that in this section Parliament were intruding only to prevent unfenced machinery getting into factories." This decision appears to accord with good sense. Had the judge come to any other conclusion, the manufacturer of certain classes of potentially dangerous machinery would be exposed to enormous risks ; and liability to such risks might be greatly increased if the Secretary of State, exercising powers conferred upon him by *ss.* (3) of S. 17 of the Factory Act, were to extend this penal provision to other machinery or plant which might "be specified in regulations."

Care is necessary, however, not to make a too general assertion regarding the liability of a man who sells machinery which is potentially dangerous. Independently of the Factory Act, the seller may be liable for an accident arising from a machine which is defective in construction in a way which is not capable of discovery by reasonable inspection (*Farr* v. *Butters Bros. & Co.* (1932) 2 K.B. 606). That is in accordance with a principle laid down in *Donohughe* v. *Stevenson* (1932) A.C. 562—generally known to lawyers as the "Ginger Beer Bottle Case." The plaintiff there alleged that he sustained injury through drinking a bottle of "stone ginger" which contained the carcase of a deceased snail. No one could say through how many hands that bottle passed on its way from manufacturer to consumer: yet it was held that the man who brewed the beverage was liable in damages to the man who drank it.

NOTES.

EXPORTS OF BRITISH ROAD VEHICLES.

ACCORDING to a statement issued by the Society of Motor Manufacturers and Traders, the largest shipments of motor cars ever made in one month were achieved during November, 1951. In all, 37,837 cars were exported in this period, 5,530 more than in the previous month, the value reaching the record figure of 13,128,131*l*. Exports of commercial vehicles during November were also the highest ever achieved in a single month, 14,298 units worth 7,425,980*l*. having been shipped overseas. Satisfactory figures for the shipment of agricultural tractors were also recorded, 11,263 units worth 4,165,714*l*. having been exported; this exceeds the October total by 444 and represents a record so far as numbers are concerned. In the same period, the value of parts and accessories exported reached 7,989,662*l*., the comparative figure for November, 1950, being 5,416,258*l*. During the month under review, Australia constituted the largest export market for cars, commercial vehicles and agricultural tractors, 15,466 cars worth 3,916,366*l*., 4,903 commercial vehicles worth 2,183,353*l*., and 2,399 tractors worth 801,860*l*., having been absorbed by this market. It is understood that the increases in November were due largely to extra shipping space having been made available by the chartering of special ships by the various manufacturers in the motor industry. Commenting on these figures, Mr. G. E. Beharrell, President of the Society of Motor Manufacturers and Traders, said that they confirmed the ability of the motor industry to maintain the high level of export business and confounded earlier rumours regarding the export of cars. He hoped that the industry's future export efforts would not be impeded by shortage of raw materials.

D'ARSONVAL CENTENARY CELEBRATIONS.

The *Journal* of the Institution of Electrical Engineers for December, 1951, contains an account by Mr. C. W. Marshall of the meeting held in Paris on Tuesday, October 23, 1951, to celebrate the centenary of the birth of Jacques Arsène d'Arsonval, the French physicist and physiologist. The meeting was held at the Sorbonne under the patronage of M. Auriol, President of the French Republic, and under the chairmanship of M. Marie, the Minister of National Education, who formally opened the proceedings. Speeches were made by M. Cheverard, M. Faral and M. Marie and demonstrations of d'Arsonval's work as an electro-physiologist, physiologist and physicist were given by Professor Binet, Professor Strohl and M. A. de Gramont. In addition, a film of d'Arsonval repeating his high-frequency experiments with his original apparatus was shown. The main achievements credited to d'Arsonval are the discovery and development of the moving-coil galvanometer in co-operation with Deprez, the development of the high-frequency electrostatic generator, the development of the vacuum flask in co-operation with Violle, and the development of an artificial muscle with which it was possible to simulate the action of the electric eel and similar creatures. It is of topical interest to other engineers to note that d'Arsonval seems to have been the first to point out the possibility of using solar heat stored in the sea to produce mechanical energy by means of the vertical temperature gradient which exists in the sea.

DIESEL LOCOMOTIVES FOR BRITISH RAILWAYS.

The Railway Executive have announced their intention to increase greatly the number of Diesel shunting locomotives used on British Railways; during the five years 1953-1957, 573 are to be added. The present stock of this type of engine is 130, but as 84 are already on order, the total at the end of 1957 should be 787. The Executive's decision was reached after an investigation into the shunting-engine position in all Regions, which showed that economies could be obtained and efficiency increased by changing from steam to Diesel traction in many of the larger marshalling yards and goods yards and in dock sidings. The provision of 573 Diesel engines will enable 635 obsolescent steam engines to be scrapped, though the implementation of the plan will depend on the permitted level of expenditure, on steel supplies, and on the manufacturers' ability to provide Diesel engines and transmission equipment. The five-year scheme provides for 432 Diesel-electric engines of 350 h.p. and 141 Diesel-mechanical engines of 150/200 h.p.; 57 of the former and 12 of the latter are to be included in the 1953 locomotive-building programme. The provision of the balance of the 141 Diesel-mechanical locomotives will be subject to the satisfactory performance of the first 12 in traffic. The Diesel-electric engines will be of the 0-6-0 type, but there will be two Diesel-mechanical types, namely, one 0-4-0 of 150 h.p. and one 0-6-0 of 200 h.p. The main frames, wheels, cab structure and mechanical parts will be built in the British Railways workshops, and the Diesel engines and electrical-transmission equipment will be purchased from contractors who specialise in their design. The advantage of Diesel operation in Britain, the Railway Executive state, is most marked in shunting yards, where the engines are employed continuously; nevertheless, trials are being continued with higher-power Diesel locomotives on general passenger and freight working. These include four 1,600-h.p. main-line express passenger and freight locomotives; one 800-h.p. Diesel-electric engine for secondary passenger and freight services; and two Diesel-mechanical locomotives—one of 1,600 h.p. for main-line and freight services, and another of 500 h.p. designed chiefly for local freight trips.

PROGRESS IN THE NICKEL INDUSTRY.

During 1951 the production of nickel in Canada totalled 275,000,000 lb., an increase of 28,000,000 lb. over the figure for 1950, and upwards of 90 per cent. of the world's production of the metal, excluding that of Russia and satellite countries. Measures to maintain and increase the outputs from Canadian nickel mines are outlined in a review of the industry made by Dr. J. F. Thompson, chairman and President of the International Nickel Company of Canada, Limited, who states that the amounts now available are to continue at the same high levels each year, and that, by 1954, an increase of 30 per cent. over that available before the outbreak of the Korean conflict should be realised. An expansion programme has been embarked upon to increase the maximum annual production of the plants of the Falconbridge Nickel Mines, Limited, Falconbridge, Ontario, from about 25 million pounds to 40 million pounds in three years. The plans of Sherritt Gordon Mines, Limited, who own deposits in the Lynn Lake area of Northern Manitoba, indicate that nickel production in this field will commence in 1953 and that its annual capacity of 17,000,000 lb. will probably be attained by 1955. The Canadian Government are assisting the Canadian National Railways to construct a 155-mile railway link to the Lynn Lake nickel-copper-cobalt deposits. The current annual rate of production of the mines and refineries of the International Nickel Company, at Copper Cliff, Ontario, and elsewhere, has recently been increased by an additional 12 million lb., to 252,000,000 lb. Moreover, the company continue to push their long-range underground mining development programme, which, when completed in 1953, will give what Dr. Thompson terms the largest non-ferrous base-metal underground mining operation in the world. Other developments include the re-opening of the United States Government's Nicaro nickel plant in Cuba, a new cobalt, nickel and copper separation plant at Fredericktown, Missouri, U.S.A., and increased outputs from the nickel mines, operated by the French firm, S. A. Le Nickel, in New Caledonia, in the South Pacific. Turning to the uses of nickel, Dr. Thompson stated that the production of all types of stainless steels was greater in 1951 than in any previous year. The aircraft industries in Great Britain, Canada and the United States, with their developments of jet propulsion, are taking increasing amounts of heat-resisting, corrosion-resisting and other complex alloy steels of high nickel content. The requirements of other Service and Government departments have likewise been heavy, as have also those of the chemical and petroleum industries. The demands on the metal for defence purposes have virtually eliminated nickel-plating for many civil applications, while the production of alloys of copper, nickel and zinc, commonly known as the nickel-silvers, is largely restricted to defence equipment. In some instances, alloys of a lower nickel content are being substituted for high-nickel alloys for such purposes as sheathing materials for electric-heating elements in domestic ranges and industrial heaters.

ELECTRICITY SUPPLY IN NEW ZEALAND.

According to the report of Mr. B. E. Davenport, general manager of the State Hydro-Electric Department of New Zealand, for the year ended March 31, 1951, shortage of water power led to a reduction in the output from hydro-electric stations from 2,688 to 2,643 million kWh. As a result, the output of the thermal stations increased from 48 to 148 million kWh and the cost of generation in these plants from 245,394*l*. to 687,339*l*. There was also an increase in the power purchased. It is clearly desirable, therefore, that the water power stations at Maraetai, Whakamaru, Cobb and Waitaki should be completed, although the report does not specifically state the extra generating capacity which will thereby be brought into use. The difficulties resulting from the dependency on water power are, further, clearly brought out in the statement that the combined water inflows to the Waikato River and Lake Waikaremoana were 11½ per cent. below the long-term average and that the inflow to Lake Taupo was less than that of the previous low record of 1914-15. By increasing the output of the thermal stations, however, it was possible to compensate these shortages without drastic measures being necessary, and even to build up the reservoir levels to some extent. It is clear, nevertheless, that the position is not entirely satisfactory and this is emphasised by the statement that, in the North Island, the search for geothermal steam is of very great importance and should be pushed ahead as far as possible. Success in this field, it is felt, would have enormous economic advantages and would provide a ready means of strengthening the hydro-electric power in the North Island, as well as opening up a source of further power for the future. In the South Island, however, it would be necessary to depend on more normal methods of production. The problem is the more important as electricity consumption continues to increase in the Dominion, as elsewhere.

CENTENARY OF CLYDEBANK SHIPYARD.

On December 17, the centenary of the founding of the Clydebank shipbuilding yard of Messrs. John Brown and Company, Limited, was celebrated in Glasgow. It was on that date, in 1851, that the firm of Messrs. J. and G. Thomson, which had been founded in 1846, opened the yard in the upper reaches of the Clyde, where was built, as the first contract, the liner Russia for the Cunard Steamship Company. In 1873, the shipyard was transferred to its present site at Clydebank, although the company's engine works continued until 1883 at Finnieston, where James and George Thomson had founded their business. In 1899, the Sheffield firm of John Brown and Company, Limited, which had been founded in 1854, acquired the Clydebank works, and continued the connection of the company with the Cunard Line, for whom such outstanding ships as the Lusitania, Queen Mary and Queen Elizabeth were built at Clydebank. The association was maintained during the centenary week by the placing with Messrs. John Brown and Company of an order for two passenger liners, each of about 20,000 tons gross, for the Cunard Line's Canadian service. The value of this order is expected to be approximately 7,000,000*l*. During the same week, also, the company demonstrated before members of the Scottish Peat Committee, the North of Scotland Hydro-Electric Board, and other interested visitors, an experimental peat-fired gas turbine, the first of its kind in the world.

THE LATE MR. ARTHUR POLLITT.—As we go to press, we learn with much regret of the death on December 23, of Mr. Arthur Pollitt, deputy controller, London Division, of the British Electricity Authority. Mr. Pollitt, who was 60 years of age, had been previously chief engineer, generation (construction) in the London Division, and, before the nationalisation of the industry, chief constructional engineer of the London Power Company.

LETTER TO THE EDITOR.

THE STEPHENSON BUILDING, KING'S COLLEGE, NEWCASTLE-UPON-TYNE.

TO THE EDITOR OF ENGINEERING.

SIR,—We were interested to read your article on the Stephenson Building, King's College, Newcastle-on-Tyne, printed in your issue of November 30, on page 681, *ante*. We notice that you refer to the dimming units in the lecture theatres as comprising a solenoid with an adjustable core. Such a method of dimming has been used for many years, but almost invariably results in a somewhat jerky or irregular variation in lamp intensity, and you will have noticed, no doubt, that the control of lamp intensity in this installation is particularly smooth.

This degree of control has been attained by means of a saturator reactor, commonly known as a transductor, which we consider to be a great improvement on the adjustable-core type of solenoid. The principle of operation is much the same, except that the variation in reactance is obtained by saturating the magnetic circuit by means of a small direct current. With a high degree of saturation the reactor has only a small impedance, but when the direct current is reduced the reactance is increased. A very small motor-operated rheostat can be used, giving very smooth control, as is witnessed by this installation.

Yours faithfully,
R. W. GREGORY & PARTNERS.

Pilgrim House,
Newcastle-on-Tyne, 1.
December 19, 1951.

OBITUARY.

MR. E. WATSON SMYTH, C.B.E.

WE have learned with regret of the death, on December 14, of Mr. E. Watson Smyth, a former principal assistant secretary in the Ministry of Labour and National Service, in which capacity he was responsible, during the recent war, for the whole work of the Government Training Department.

Edward Watson Smyth was a native of Sussex, having been born, on December 17, 1883, at St. Leonard's-on-Sea, where also he received his early education, at Rothbury School. At the age of 12, he went to Cheltenham College, which he left in 1900 to enter upon an engineering apprenticeship in the marine-engine works of Laird Brothers, Limited (now Cammell Laird and Company) at Birkenhead. There he had a varied training, including periods in the pattern shop, the millwrights' shop and drawing office in addition to the usual routine of an apprentice engine-fitter; concurrently, he attended classes at Liverpool University. He completed his apprenticeship in 1905 and remained for a time in the drawing office. By then, the connection had been established between Laird Brothers and Charles Cammell and Company, of Sheffield, and this provided an opportunity for Smyth to go to Sheffield in December, 1906, as assistant machine-shop manager in the Grimesthorpe works of the combined firm of Cammell Laird and Company. He retained this post until the early part of 1908 and was then transferred to the company's head office, at the Cyclops Works, as chief assistant to the general manager, in which position he was responsible for the installation of an extensive range of heavy steelworks equipment.

In 1909, Smyth left Cammell Laird and Company and took up an appointment as works manager with Joshua Buckton and Company, at Leeds, where his principal concern, during the next six years, was with the design and manufacture of plant for the production of guns, supplied to Woolwich arsenal, the Russian Imperial Arsenal, and elsewhere. In 1916, he transferred to Taylor Brothers and Company, Limited, Manchester, as senior director. He remained with them until 1940, and, during this period, was closely associated with the introduction of the Wood high-pressure boiler;

he presented a paper before the Institution of Mechanical Engineers, in 1930, on "General Operation Experiences with the First 'Wood' Steam Generator." This paper was reprinted on page 149 of our 129th volume, in the issue of January 31, 1930. Mr. Smyth had been 14 years with Messrs. Taylor Brothers when he was seconded to the Ministry of Labour for "special duties" which eventually proved to be the organisation of the Government scheme for training men for munitions work; it involved the establishment of 39 main training centres and the organisation of a large number of subsidiary schemes in large works, munition factories, etc., which was recognised in due course by the award of a C.B.E. Mr. Smyth was a member of the Institution of Mechanical Engineers, of the Institute of Fuel and of the Society of Sheffield Engineers and Metallurgists, and a Fellow of the Institute of Industrial Administration.

INTERNATIONAL CONFERENCE ON ABRASION AND WEAR.

(*Concluded from page* 791.)

DR. F. P. BOWDEN, continuing the discussion on Dr. R. D. Stiehler's paper on "Some Factors Influencing the Road Wear of Tyres"—the final paper in the International Conference on Abrasion and Wear, held at Delft on November 14 and 15—thought that Dr. Stiehler had partly answered the query that Dr. Bowden had put in his own paper on the previous day, concerning the actual temperature generated at the actual abrading surface. He inquired whether Dr. Stiehler could say what surface temperature was generated in a motor-car tyre running on an asphalt road at, say, 60 miles an hour. If the slip was appreciable, he could readily understand that the temperature would be quite high and could lead both to accelerated chemical attack and to a change in the rate of wear. Clearly, the important factor from the point of view of physical wear was the mechanical property of the rubber, not at room temperature but at the temperatures which occurred at the interface when running. From general considerations it might be expected that the surface temperature under many conditions (e.g., if the brakes were applied) would be sufficient to cause local melting of the rubber surface in the region of contact. Had any attempts been made to measure experimentally the temperature at the actual surface? It should not be unduly difficult to do so.

There was, Dr. Bowden continued, a second possible cause of high temperatures in the surface layers of the rubber. If one hit an explosive, it exploded; why? It was very rare to break up a molecule by mechanical means; but a solid contained spaces, and high temperatures might be produced by the adiabatic compression of air in such small pockets, either present in the material or entrapped between the surfaces. The photomicrographs of worn rubber surfaces that had been shown during the Conference suggested that air might be entrapped and compressed in that way. In liquid, plastic and solid explosives, it was the presence of such tiny air pockets that was largely responsible for the initiation of the explosion by impact or shock. They were very small—perhaps less than a thousandth of a centimetre in diameter—and were very difficult to detect, even with a microscope. If the compression ratio was 20 : 1, the rise in temperature of an air pocket was about 450 deg. C., and, with higher compression ratios, a temperature of 1,000 deg. C. was easily reached. It had been found that that effect was often responsible for initiating chemical reactions in solids, particularly if they were readily deformed. Did Dr. Stiehler consider that the same effect could be significant in a motor-car tyre when running on the road?

Dr. A. Schallamach, who was the next speaker in the discussion, did not agree that most damage to tyres was chemical in origin; the striped nature of the abrasion pattern, and the absence of any smell of burning rubber, convinced him that it was not so. He found it difficult to see how any such process could produce the orderly markings that he himself had observed and had illustrated in his own paper. If cornering caused a 5 h.p. increase in the energy absorbed by a tyre, how did a small car ever succeed in rounding a corner? In the United States, the Holland Tunnel had been swept through, and handfuls of abraded rubber were collected; yet one seldom smelt burning rubber on the road.

Dr. R. Houwink asked Dr. Stiehler what was the connection between abrasion and slip.

Dr. Stiehler, replying to the discussion, said that Mr. Braber was correct in supposing that the geometry of the tread design was responsible for the decreasing rate of depth loss as a tyre became worn. If the geometry of the tread was such that the area of contact between the tyre and the road remained constant, either the depth method or the weight method could be used; but such a condition was exceptional because most tread elements had a trapezoidal cross-section and, generally, the tread radius did not remain the same. Graphs based on cumulative data failed to show clearly the differences in rates of wear during successive periods. Moreover, they were often misleading when extrapolated (e.g., in estimating tread life) because of the enormous effect, on the trend of such a graph, of the rate of wear during the early part of the test. His own experience was that the weight method was to be preferred to the depth method, even in studying the relative rates of wear of rubber compounds in tyres of the same design. Usually, the depth method did not permit the substitution of a new tyre of identical construction for one that had failed on test; and more miles of testing were needed to obtain the same validity in the estimates of rates of wear by the depth method. So far as simplicity of testing was concerned, there was little to choose between the two methods; a balance was more expensive than a depth gauge, but it was cheap by comparison with the cost of a road test.

In reply to Mr. Bielstein, Dr. Stiehler agreed that statistical difficulties arising from the changing rates of wear were not valid reasons for rejecting the depth method. If a tyre was tested until the tread was smooth, the tread life could be determined directly from the odometer reading; but his experience was that an evaluation of tread life could be made in fewer miles of road test when using the weight method than with the depth method, and was less influenced by the tread design. Caution must be exercised, however, in applying the power law mentioned by Mr. J. M. Buist. The tread design did influence the rate of wear, so the same design should be used in comparing different tyre compounds. In comparing different brands of tyres, it was necessary to determine both the rate of wear and the amount of the tread in order to calculate the tread life; and, in such cases, biased and erroneous results were likely to be deduced from depth data alone. A laboratory abrader should aim to reproduce road results obtained by the weight method.

Replying to Mr. Hesselink: within the accuracy of testing, any differences in the hardness of the surface and of the underlayers of the tread, resulting from differences in the state of cure, appeared to have no influence on the rate of wear. Apart from that, Dr. Stiehler said, he knew of no data comparing the wear behaviour of tyre treads having surface layers appreciably harder or softer than the substratum. It was known that inflation pressure influenced the rate of wear, but probably it did so by varying the amount of slip that occurred between the tread surface and the road surface. Water on the road did not increase the rate of wear, but the resultant effect on temperature could overshadow changes in the coefficient of friction.

Dr. Stiehler agreed with Dr. Bowden that the temperature of the tread surface at the point of contact with the road was probably very high, but, so far as he was aware, no quantitative information was available about it; he would like to obtain some measurements. Under conditions of severe slip, sufficient to produce streaks of liquefied rubber on a dry road surface, the temperature must be considerably above 400 deg. C. in order to depolymerise the rubber molecules. Undoubtedly, there were small air bubbles between the tread and the roadway; but, in view of the small forces required to deform rubber, he doubted whether the bubbles were compressed to ratios of 20 : 1 or higher. The oxygen in the bubbles might, however, oxidise the rubber while it was under strain and at the elevated temperatures that occurred during the time of contact between tread and road. If tyres could be abraded in the absence of oxygen, it was probable that very different wear results would be obtained. It was believed that some such mechanism was responsible for the positive temperature coefficient and abrasion observed in treads of natural rubber and the negative coefficient with treads of synthetic rubber, since the two kinds of rubber reacted somewhat differently to heat and oxidation. If the surface temperature were raised sufficiently, a point must be reached when the temperature coefficient of synthetic-rubber treads also was positive.

It had been pointed out in the discussion on Dr. Schallamach's paper that the ordered patterns which he presented were not characteristic of normal wearing of tyre treads; they indicated an abnormal type of wear. The surface of a worn tread was usually smooth, with a matt finish. The available evidence indicated that wear occurred on a molecular scale, rather than by the removal of discrete particles of rubber; though, of course, on gravel roads, or on road surfaces containing sharp particles, rubber might be removed by cutting as well as by abrasion. In such cases, an ordered array or pattern on the tread surface might be produced. Mechanical defects in the vehicle might cause a similar result. The chemist could change tyre wear by, perhaps, 100 to 130 per cent.; but the engineer, by altering the tread design, could affect it by 100 to 250 per cent. Finally, in reply to Dr. Houwink, Dr. Stiehler agreed that slip was closely connected with the abrasion of tyres, though it was only one factor among many. The ideal tyre, from both safety and abrasion standpoints, would be one that had no slip.

In a subsequent written contribution, Professor H. Blok suggested that knowledge of the surface temperatures reached by tyres in service might be obtained by using, as fillers in the rubber compound, various "thermicolours," i.e., commercially available dyestuffs which showed either reversible or irreversible changes of colour at different temperatures. The changes could be ascertained by microscopical examination.

SUMMARY.

Dr. H. C. J. de Decker, the chairman of the Conference, concluded the proceedings by reviewing the contents of the eight papers and the results of the discussions. There appeared, he said, to be at least three possible means of taking a cross-sectional survey of the field of wear. The first was by studying the types of material, since, whether this was hard or soft, wear was something that happened at the surface, causing (in Professor Blok's words "undesirable migration" of the material. Secondly, there was the method of analysis according to the basic factors which promoted wear; the complexity of wear phenomena, and the difficulty of studying them, was largely due to the circumstance that rhose factors rarely operated separately. The third approach was by considering the factors which counteracted wear. It had been pointed out by Mr. J. M. Buist that the practical aim in wear testing was to be able to predict or calculate long-term wear properties from relatively short tests. If such predictions should become practicable, they should lead to some form of wear rating numbers, such as had been suggested by several of the contributors of papers. Prediction could only be accomplished, however, when all the determining factors were fully known, which certainly was not yet the case; therefore, research on the fundamentals of wear must continue. The identification of the primary aggressive force in wear processes was, in his opinion, the biggest problem. It appeared to be of little use to construct new kinds of more or less arbitrary measuring apparatus for abrasion or wear; the only useful course was to make more measurements in actual practice (including tests that were imitations of actual practice) or on well-defined elementary processes. There was much work to be done, and the utmost co-operation and team work was desirable. Knowledge must be collected from research on entirely different materials so that wear could be seen, not as specific problems of rubber or steel or fibres, but as one general problem of materials research.

STARTER FOR AIRCRAFT TURBO-JET ENGINE.

THE PLESSEY COMPANY, LIMITED, ILFORD, ESSEX.

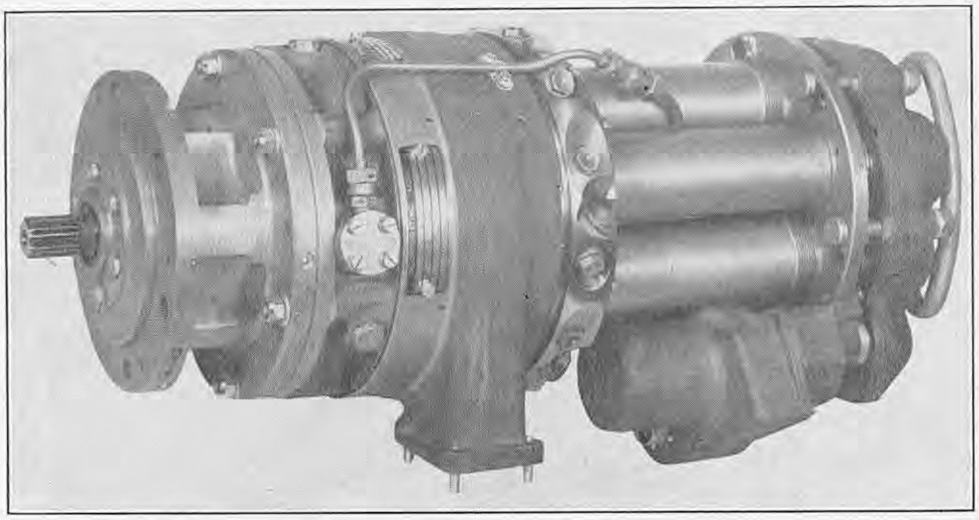
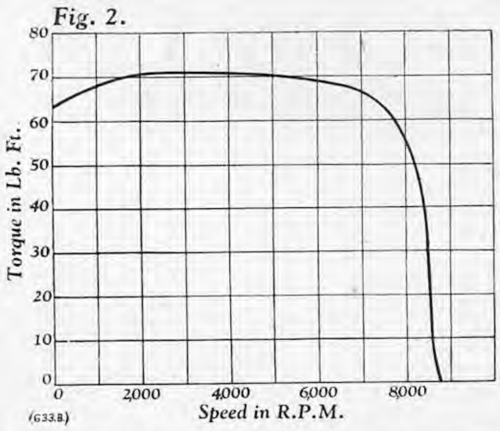
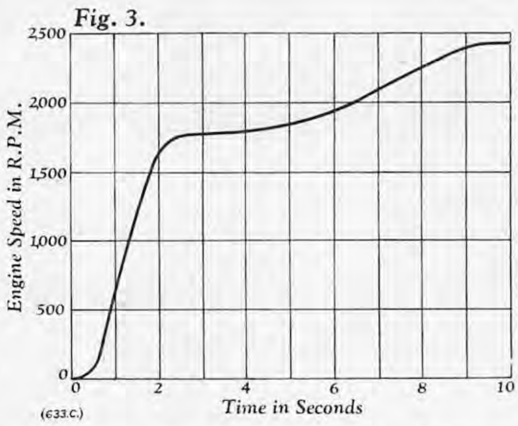


FIG. 1.





CARTRIDGE STARTER FOR THE "NENE" TURBO-JET ENGINE.

THE turbine starter illustrated in Fig. 1 on this page has been designed and developed by the Plessey Company, Limited, Ilford, Essex, for use with the Rolls-Royce Nene 4 turbo-jet aircraft engine. It is a light but robust unit employing power cartridges as the operating medium, six such cartridges, sufficient for three consecutive starts, being carried in a special container. The total energy output is 64,000 ft.-lb., which is delivered in a working period of two seconds, the subsequent rapid but smooth acceleration enabling engine idling speed to be reached in under ten seconds. Curves which show the starter torque plotted against its speed, and the engine speed plotted against time, are reproduced in Figs. 2 and 3, respectively.

Firing of the charge is accomplished by means of a control panel, the starting cycle being initiated by depressing a button in the pilot's dockpit. The sequence and timing of the various operations are then controlled by the panel, the operations including the closing of the throttle by-pass when the engine has reached normal idling speed. The panel also incorporates means to prevent damage being done to the unit should an attempt be made to start an engine already rotating at a high speed. Contra-rotating turbine wheels are employed and, during the working cycle, the gases from two cartridges disposed diametrically opposite are led through nozzles to the turbine blades. The drive from the rotors is taken through a reduction gearbox to the output side of the starter, which is fitted with a splined shaft and flange machined to the Society of British Aircraft Constructors' standard R.S. No. 302. The peak speed of this shaft is 8,750 r.p.m., corresponding to a rotor speed of 38,000 r.p.m.

A multi-plate clutch is incorporated in the drive, for the absorption of peak loads during engagement, and an overspeed safety device is provided to limit the rotor speed in the event of a failure in any part of the drive mechanism. Lubrication of the bearings, gearwheels, etc., is effected by a built-in pump which meters the required small amount of oil from the main lubrication system of the engine at each start. One of the difficulties to be overcome with starters of this type is that of obtaining a reasonable life from the turbine blades under the arduous conditions in which they operate. Considerable progress in this direction has been made, however, and the Plessey Company state that one of the starters of this type has completed a life-test of 750 shots without it having proved necessary to replace any major component; this number of starts, it may be added, is treble that required in the official type tests.

RURAL ELECTRIFICATION IN EUROPE.—Joint international action to promote the electrification of rural areas in Europe in the most efficient and economical way was outlined at a recent meeting of the United Nations Economic Commission for Europe in Geneva. This action is based on the policy of interchanging experience between those countries which are advanced in rural electrification and those which are practically undeveloped; and will include a major investigation into both technical and economic questions. A second related study will attempt to determine the reasons for the large variation in the constructional costs of hydro-electric plant in the different European countries, so as to obtain data which might be useful in developing new sources.

ENCOURAGEMENT OF MECHANISED FARMING IN THE COLONIES.—The importance attached to the development of agriculture in British Colonies is exemplified by the fact that the Secretary of State for the Colonies has appointed a body to be known as the Colonial Agricultural Machinery Advisory Committee, which, as its name suggests, is to be responsible for advising the Minister on problems concerned with the development, and expanding the use, of agricultural machinery in colonial territories. The setting up of such a committee, it will be remembered, was recommended by the British African Land Utilisation Conference held in 1949. It will not confine its attention to Africa, however, as the terms of reference have been widened to include all colonial territories. The Committee will meet under the chairmanship of Mr. C. G. Eastwood, vice-chairman of the Colonial Advisory Council of Agriculture, Animal Health and Forestry, and its members include experts from the Colonial Office, the Crown Agents for the Colonies and the leading British manufacturers of agricultural machinery.

TRANSFORMER OILS.

Two papers dealing with various matters connected with transformer oil were read at a meeting of the Supply Section of the Institution of Electrical Engineers on Wednesday, December 19. The first of these, which was entitled "Inhibited Transformer Oil," was presented by Messrs. W. R. Stoker and C. N. Thompson, and in it the authors pointed out that the oxidation, which causes sludging and the formation of acids, may be prevented by using an inhibited oil. The substances employed for this purpose include catalyst passivators and de-activators, oxidation inhibitors and indirect anti-oxidants. Some of these, though effective in the laboratory, may, however, not be as suitable in a transformer. Oxidation inhibitors are preferable because they operate whether catalytic metals or compounds are present or not; and being relatively inert, except for their designed action, have normally no harmful effects. These inhibitors are usually of the phenolic or amino types, which react with the highly active initial chain-carriers converting them into inactive molecules and thus terminating the reaction chain. In this process the inhibitor is functioning to suppress oil oxidation. At the end of this "induction period" oil oxidation occurs at about the same rate, in the same way, and by the same course, as it would have done if had been no inhibitor.

Various accelerated ageing tests have been devised, including the Michie oxidation test described in British Standard Specification No. 148, 1951. Nearly all these tests are of the fixed-time type and the times are short compared with the induction periods. They are therefore liable to be unsuitable for the full evaluation of inhibited oils. This drawback can be overcome by tests in which the rate of oxidation is observed by continuously measuring the amount of oxygen absorbed by the oil. These tests can be continued until the oil has absorbed a definite quantity of oxygen, which is sufficient to cause it to deteriorate enough to make it unsuitable for further service in a transformer. As these laboratory tests alone cannot be relied upon fully to assess the probable performance of the inhibited oil in service trials have been made with it in transformers. The inhibited, oil, however, has not yet been oxidised to the end of an induction period; and it will therefore be some time before definite conclusions can be drawn as to the extent of the improvement obtainable. The increase in oxidation stability over that of uninhibited oil is nevertheless considerable and may be sufficient for the oil to outlast the life of severely rated transformers.

Inhibited oil is likely to find its widest application in distribution transformers or other apparatus in which the conditions favour oxidation. Its use appears to offer no particular advantage in switchgear and other applications where oxidation is not a major factor. The usual methods of testing transformer oil in service, particularly those of neutralisation value and electric strength, are equally applicable to inhibited oil. Furthermore, by making periodic laboratory measurements of the induction period during the service life of the oil the course of inhibitor depletion can be followed. The familiar methods of purifying transformer oil by filters and centrifuges are effective with inhibited oils and have no deleterious effect upon them. Strongly adsorbent materials, however should not be used. The use of inhibited oil should remove the limitations on transformer design caused by oxidation instability. The limiting factor in transformer operating temperature will then be the thermal or oxidation stability of the solid insulation and not that of the oil. As more practical experience of inhibited oil is acquired advantage could be taken of its enhanced oxidation stability to produce smaller, and perhaps more economical, transformers capable of withstanding more severe operating conditions.

In the second paper on "The Stability of Oil in Transformers," Messrs. P. W. L. Gossling and L. H. Welch summarised operating experience with transformer oils from the aspect of sludge formation and the increase of acidity with life. They also described tests which are designed to study the correlation of increasing acidity found in service with predictions of performance based upon the Michie sludge test. While the deterioration of the oils in the 17 transformers investigated has not proceeded sufficiently far to allow final conclusions to be drawn, there is a clearly established trend towards a greater degree of deterioration, as assessed by acidity formation, of the oil which gave a high degree of acidity in the sludge test. The three oils of low-acidity type tested are at present showing good stability. These investigations, over an extended period, have shown that, except where abnormal conditions of operation apply, transformers can be operated with the minimum of maintenance for very long periods when the oil complies with B.S. 148: 1951.

The conclusions drawn are that oils in transformers fitted with conservators rarely develop undue acidity. Oils in transformers without conservators tend to develop acidity, but the oil (B.S. 148) may be expected to be satisfactory for use in such transformers and, under normal conditions, is likely to last for the expected life of the transformer. The low rate of rise of acidity of oils complying with this specification should make testing necessary only every two or three years, unless the load or temperature conditions are severe. Where the loading of a system is suitably arranged it should be possible satisfactorily to use the simplest types of indoor transformer, having lower total maintenance costs than those more elaborately fitted, with consequent savings in capital costs of the unit and its chamber, where special headroom might otherwise be necessary.

FLASH BUTT-WELDER FOR STEEL STRIP.

BRITISH FEDERAL WELDER & MACHINE CO., LTD., DUDLEY, WORCESTERSHIRE.

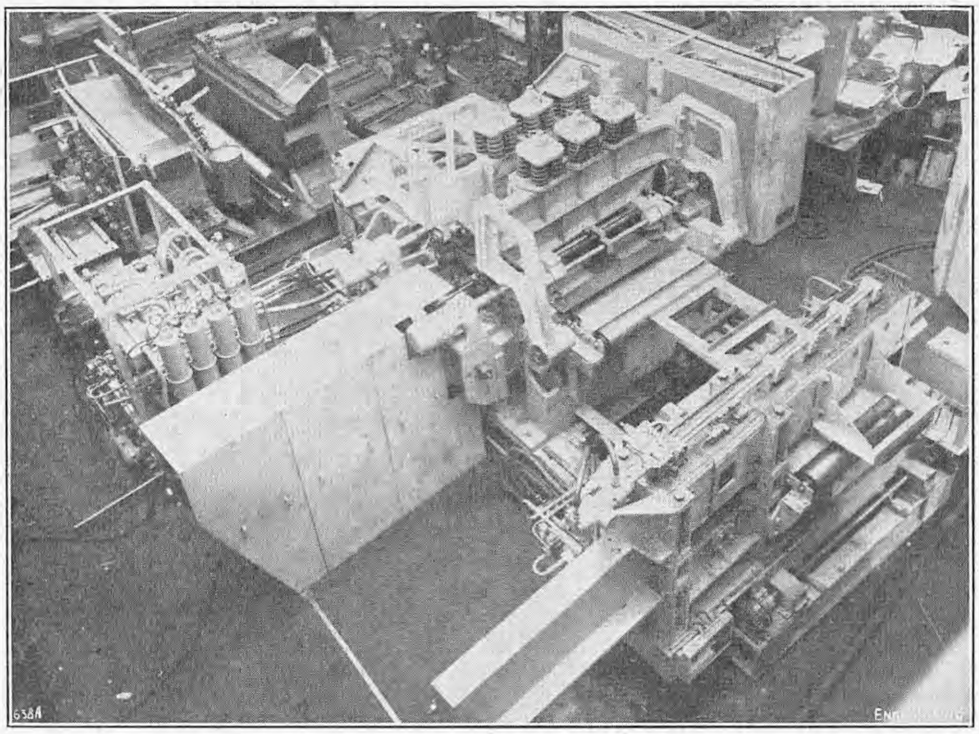


FIG. 1. GENERAL VIEW OF WELDER AND STRIPPER.

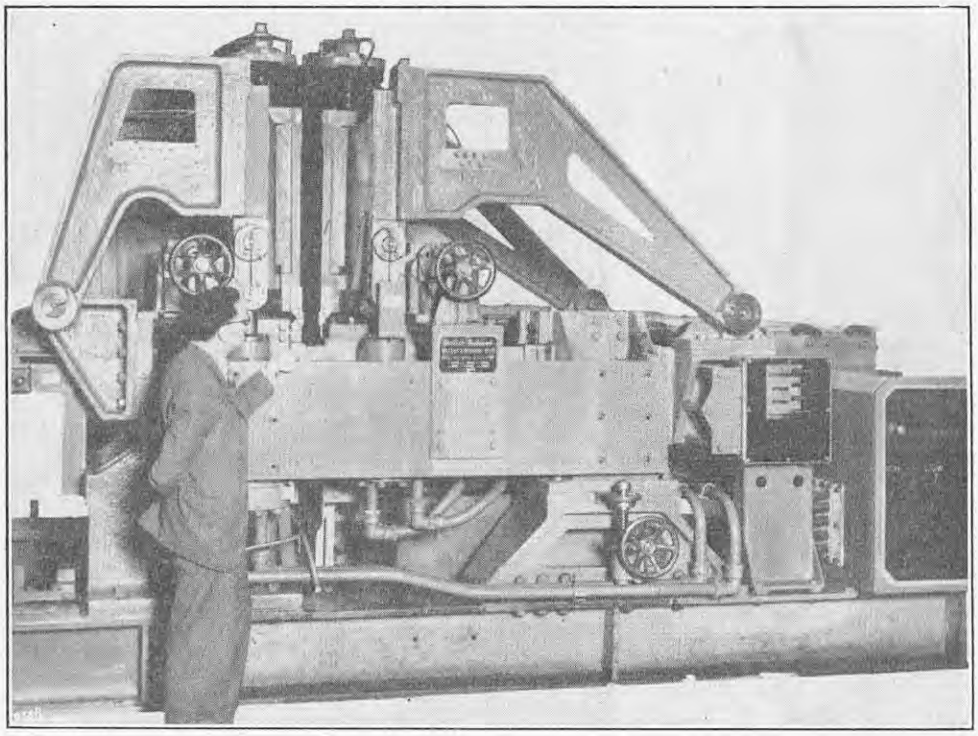


FIG. 2. FRONT OF MACHINE, SHOWING CONTROL PANEL.

FLASH BUTT-WELDER FOR STEEL STRIP.

THE continuous pickling of steel strip requires the provision of some means of welding the leading edge of a new coil of strip to the trailing end of the preceding coil, so that a continuous strip may be fed into the pickling line. The welding machine illustrated in Figs. 1 and 2, herewith, has been constructed for this purpose by the British Federal Welder and Machine Company, Limited, of Castle Mill Works, Dudley, Worcestershire, and is now at work in the pickling line at the Trostre works of the Steel Company of Wales, at Llanelly. It is of the flash butt type and can deal with steel strip up to a maximum width of 48 in. and a thickness of 0·15 in., and is designed to complete and trim a weld in a maximum cycle time of 90 seconds from start to finish. The overall floor space occupied is approximately 20 ft. by 15 ft., the height of the machine is 10 ft., and its weight is about 70 tons.

There are two principal units in the complete machine, one for welding and the other for stripping the flash from the weld. They are mounted in tandem on a common bed, the welding unit being fixed and the stripper having a certain movement in the direction of motion of the strip. A general view of the complete machine, in the makers' works, is given in Fig. 1, herewith, the welder being in the centre and the stripper in the right foreground. Behind the welding unit, on the left, are the hydraulic pumps and control valves, the latter operated by motor-driven cam timing gear. The structural framing of the machine is fabricated from steel plate. The operation of the machine is controlled from a position at the front, shown in Fig. 2, but there are four emergency stop buttons at various points, in addition to the one on the control panel. There is a separate resetting controller to return the machine to the starting position after an emergency stop has been made. The main welding contactors and the gear for regulating the sequence of operations are in separate cabinets, not shown in the illustrations.

The operation of the machine is simple and largely automatic. When the hydraulic pump has been started and pressure has been built up, a signal light on the control desk indicates that the machine is ready for use. The strip normally passes freely through the open clamps until its tail end reaches the machine. The clamps then grip the end of the strip while an air blast removes any loose flash which may be lying on the lower die after the previous weld. The cleaner bar, which serves also as a gauge to position the strip ends at the correct distance apart, is advanced by hydraulic power from its housing; the end of the retracted bar can be seen projecting from the housing, to the left of Fig. 1. On entering, it removes any scale adhering to the dies and temporarily rests in that position. The clamps are then released and the trailing end of the strip is "inched" back by pinch rolls until it butts against the bar, and the leading edge of the new strip is similarly butted against the other side of the bar. Both strips are clamped while the bar is withdrawn into its housing. A motor-driven centring device adjusts the two strips so that they are truly in line. The pinch rolls are part of the mill equipment and not of the welding machine, but the inching controls for them are mounted on the machine desk. Looping pits are provided at the site to allow the temporary stoppage of the two strip ends for welding, without interrupting the operation of the pickling line.

The two ends being in line, clamped, and at a gauged distance apart, the welding start controller is operated and the following sequence proceeds automatically. First, the leading end of the incoming strip, the clamps of which are mounted on a movable table, are slightly withdrawn from contact with the gauge bar. The bar then retracts to its housed position and the table moves forward until the ends of the two strips butt together. At this point the process can be stopped by the operator if he wishes to check the alignment of the two edges, and restarted by operating the appropriate controls; otherwise, the automatic sequence proceeds. The current is now switched on, burning off a predetermined amount of material from the strip ends while the heat travels back into the metal, bringing it into a plastic condition; this is automatically timed and is adjustable. At the end of the flashing period, the current is switched off and the strip ends are forced together hydraulically to upset the joint; the amount of the upsetting motion is also controlled automatically, and can be adjusted. When upsetting is completed, the moving table stops, the clamps open to release the strip, and the table returns to the starting position, which resets the machine for the next weld.

The flash has now to be removed from the weld, and here the makers have introduced a novel feature to overcome the difficulty of locating the weld exactly in line with the stripping tools. The stripper is mounted on a carriage with flanged wheels, running on the base of the machine, and can be moved laterally by means of hydraulic cylinders, actuating rack and pinion gears, and provided with a variable speed control. The welded strip is fed forward until the weld is approximately in line with the stripping tools, and the stripper itself is then moved as necessary to obtain precise alignment. The steel strip is clamped hydraulically and the stripping start controller is operated. The stripping tools, driven by an electric motor through a worm reduction gear, then move along the line of the weld, above and below the steel strip, and clean off the flash. There is a series of cutters of high-speed tool steel, set in progressive steps like the teeth in a broach, the last pair above and below the weld being set at a distance apart corresponding to the thickness of the unwelded steel, so as to plane the weld to a smooth surface that will pass evenly through the rolls.

At the conclusion of the stroke, the clamps re-open and the tools return automatically, thus setting the stripping machine for further use. The tools are mounted in easily detachable holders to facilitate rapid replacement. A setting jig is provided on the side of the stripper for use in adjusting the tools after grinding or in fitting new tools. Spare tools and holders are included in the equipment.

THE UNIVERSITY AND THE CIVIL ENGINEER OF THE FUTURE.*

By PROFESSOR J. B. B. OWEN, D.Sc.

(*Concluded from page* 792.)

WHILE university training should give the student a broad background, I consider that university teaching time can be best spent on those subjects which present the greatest difficulty to students. Among these, at the head of the list, is mathematics. At one time, engineering text-books almost apologised for using the methods of the calculus, yet Fairbairn used them in his calculations on tubular bridges about a hundred years ago. Our attitude to-day is Fairbairn's: we will use the best techniques which are available to us. Mathematics provides us with very powerful techniques, but, as in engineering, the matter presented to engineers has to be selected so that methods not specifically dealt with in the course can be quickly grasped afterwards if required; this selection is not easy. Who, some years ago, would have forecast that a powerful way for engineers to deal with awkward differential equations would be to turn them into approximate finite difference equations or just to feed them into a machine?

The development of quality control has brought statistics into the engineering picture, and an extensive use is already being made of its ideas in the study of road accidents, rainfall, sewage disposal, loads on structures, etc. These developments will radically affect the basic reasons why, for example, one uses certain stresses in structural design, or why one form of road junction is used instead of another. Civil engineers will not place much faith in the results obtained unless they understand the basis on which they are developed and are able to appreciate the factors which have been omitted from the calculations.

Again, the increasing need for economy in the use of materials—and civil engineering projects use large quantities of materials—will, in many cases, force upon us the increased use of thin sections. These will need to be stabilised and protected against corrosion and fire. The civil engineering graduate should be equipped with basic ideas on stability which will enable him to proceed beyond the elementary concepts of the behaviour of a strut in the elastic range. We might try to get even these ideas correct. Struts do not necessarily fail if loaded above their critical loads; in their buckled state, they may be used as soft springs.

At least the elementary notions of elasticity, and perhaps of the calculus of variations, would seem desirable. Are other fairly recent developments going to submerge the unfortunate undergraduate, after a little "relaxation," into a sea of iteration methods and matrices? It would appear that the need for introducing special mathematical contributions into some engineering postgraduate courses will have to be borne in mind.

Technical developments in civil engineering are taking place at such a rate, and over such a wide field, that their introduction into the undergraduate course as specific subjects would completely overload it. On the postgraduate level, something might be done, provided that facilities, staff and postgraduate students can be brought together. The subjects dealt with would depend upon the nature of the facilities and the staff made available. If universities are to avoid becoming retailers of second-hand information, there must be adequate facilities. These might appropriately be such of those available to the research establishments and practising engineers as the universities can handle without impairing their teaching efficiency. One would also like to see at each university a strong flavour of local interest permeating some part of the work.

First among the facilities needed to make research and postgraduate courses in civil engineering possible at the university are appropriate means for measuring; preferably portable measuring apparatus, so that, with the co-operation of practising engineers, experimental work can be extended beyond the confines of the laboratory walls, and observations made on the performance of civil engineering works. Facts are fundamental to any real knowledge of engineering performance. In structural work, for example, equipment for recording strains is essential. Solitary strain gauges rarely give information of value. A large number of gauges needs a specially trained staff to handle them and a large staff to analyse the results before a start can be made to appreciate their significance. Even then, the wood may not be seen for the trees. It is better to set out with one small definite aim in view. A project then comes within what a university can tackle, and in this way the university can help the student to criticise the significance of the results of researches and cultivate in him an attitude which will enable him to devise some way of tackling any problem which he may meet.

Although portable apparatus extends the experimental work of a university beyond the confines of its walls, full-scale investigations have limitations. Rarely will it be possible to press investigations to the stage when failure is imminent and so obtain some information on the margin of safety available and the change in behaviour as plasticity replaces elasticity. Something is necessary to bridge the gap. Fairbairn, who was in many ways a pioneer, found model tests necessary and useful. Nowadays, facilities are available for doing model and full-scale tests, but the cost of providing test specimens alone, for use in some modern straining frames, would probably strain university finance also, and the handling of the test equipment would be a major operation. If we are to make any headway in the university it has to be on a more modest scale, and in the nature of the apparatus found at some of the smaller research establishments, and at some university engineering schools, there is encouragement that something useful can be done. Laboratory tests used in conjunction with field tests may at least give an indication of the scale effects.

The facilities available to even the staff of our national research establishments are, in many cases, quite small compared with those available in America and possibly, too, in Russia. We still find, however, good work done in small well-equipped laboratories. A good deal depends upon the man doing the research and on the encouragement he receives from his colleagues. It may offer encouragement to some to have heard, in the recent British Association meeting in Edinburgh,* of a most significant contribution made by the staff of a comparatively small laboratory to the available knowledge on the brittle fracture of mild steel. At last, tests have been devised which show a significant decrease in strength as the character of the failure changes from ductile to brittle. Locked-up stresses, poor welding procedure, poor structural design, low energy absorption, etc., all have been blamed for the premature structural failures which occurred, and they may well have been responsible for starting cracks; but these alone are poor excuses for the failure of a whole galaxy of earlier tests to produce evidence of a decrease in strength. Those who are privileged to work in small but well-equipped laboratories may take heart from achievements of this kind.

The ideal postgraduate course of lectures is one given by a team of university lecturers who have been doing research in the subject in which they are lecturing, backed up by practising engineers who have been coping with the practical difficulties of applying this work in the field. University staff should be encouraged to spend some time working at research establishments and in engineering works, and one would welcome the addition of lecturing and laboratory instruction from itinerant members of the research establishments. This procedure should result in a balanced treatment of the subject considered, provided that the postgraduate student himself also undertakes some, even small, investigation in his field.

The most important member of the postgraduate team is the postgraduate student. In my view, after the civil engineering student has taken his initial degree, his next year or so is best spent in obtaining practical experience. At some time, he has to fit in two years' military service. By the time that he has done all this, he is perhaps a married man with a family. How can he now afford to return to a university postgraduate course, even if he has a scholarship, if his effective wage is less than that of a labourer? His family is the one we need to encourage, and I understand that some of our more progressive and larger firms have already seen this problem and are providing the postgraduate student with adequate funds on the condition that he agrees to return to their service for a reasonable period after completing his studies. The smaller firms may not be able to do this. The Department of Scientific and Industrial Research now helps on occasions, but, in my view, some adequate postgraduate scholarship scheme is essential. Can we have a little more of the humanities here?

The present economic position is such that the student's most expedient procedure is to follow straight on after his initial degree with a postgraduate course. Provided this course further equips him to find out for himself what he does not know, and gives him leisure and time to think and not just swot for examinations, it will give him a breadth that, some employers complain, graduates lack; but it is not, in my view, the ideal at which we should aim.

I am aware that I have far from exhausted my subject. Civil engineering is international. The Hawksleys and Deacons of our day would be just as interested in the Snowy Mountain scheme in Australia, of turning rivers northward, as they would be in the Russian project of turning rivers southward, and the profession could have a considerable integrating influence in the world. It seems to me that, even when adequate facilities are provided, the success of the university's contribution to civil engineering of the future depends not only on those whose privilege it is to teach and carry on research in civil engineering, but on the co-operation received from those of scientific training, those nurtured in the humanities, those engaged in full-time research in the establishments of this and other countries and those employed in civil engineering practice.

* **Inaugural public lecture given at the University of Liverpool on December 7, 1951. Abridged.**

* ENGINEERING, October 5, 1951 (page 445).

FORTHCOMING EXHIBITIONS AND CONFERENCES.

THIS list appears in the last issue of each month. Organisers are invited to send to the Editor particulars of forthcoming events.

PETROLEUM INDUSTRY EXHIBITION.—Monday, December 17, to Sunday, January 27, 1952, at the Royal Scottish Museum, Edinburgh. Organised by the Shell Petroleum Co., Ltd., St. Helen's-court, London, E.C.3 (Telephone: AVEnue 4312); and the Anglo-Iranian Oil Co., Ltd., Britannic House, Finsbury-circus, London, E.C.2 (Telephone: CENtral 7422). See also page 480, *ante*.

NEW BUILDING MATERIALS AND TECHNIQUES EXHIBITION.—Friday and Saturday, January 18 and 19, 1952, at the Royal York Hotel, Toronto. *Agents:* Tides, Ltd., 1, Hanover-square, London, W.1. (Telephone: MAYfair 1101.)

INTERNATIONAL RADIO AND ELECTRONICS EXHIBITION OF INDIA.—Saturday, February 9, to Friday, February 29, 1952, at Bombay. For further information, apply to the secretary, Radio and Electronics Society of India, Fateh Manzil, Opera House, Bombay, India.

INTERNATIONAL AGRICULTURAL MACHINERY EXHIBITION.—Sunday, February 17, to Sunday, February 24, 1952, at Brussels. Apply to the secretary, Société de Mécanique et d'Industries Agricoles, S.A., 29, Rue de Spa, Brussels, Belgium.

BUSINESS EFFICIENCY EXHIBITION.—Tuesday, February 19, to Friday, February 29, 1952, at Bingley Hall, Birmingham. Organised by the Office Appliance and Business Equipment Trades Association, 11-13, Dowgate-hill, Cannon-street, London, E.C.4. (Telephone: CENtral 7771.) See also page 636, *ante*.

GERMAN INDUSTRIES FAIRS, HANOVER.—*Light Industries:* Wednesday, February 27, to Sunday, March 2, 1952, at Hanover. *Heavy Industries:* Sunday, April 27, to Tuesday, May 6, 1952, at Hanover. *Agents:* Schenkers, Ltd., 27, Chancery-lane, London, W.C.2. (Telephone: HOLborn 5595.)

INTERNATIONAL AGRICULTURAL MACHINERY EXHIBITION.—Tuesday, March 4, to Sunday, March 9, 1952, at the Parc des Expositions, Paris. Organised by the Union des Exposants des Machines et d'Outillages Agricoles, 38, Rue de Chateaudun, Paris 9e.

"DAILY MAIL" IDEAL HOME EXHIBITION.—Tuesday, March 4, to Saturday, March 29, at Olympia, London, W.14. Organised by the *Daily Mail*, New Carmelite House, Carmelite-street, London, E.C.4. (Telephone: CENtral 6000.)

VIENNA SPRING FAIR.—Sunday, March 9, to Sunday, March 16, 1952. *Agents:* British Austrian Chamber of Commerce, 29, Dorset-square, London, N.W.1. (Telephone: PADdington 7646.)

GENEVA INTERNATIONAL MOTOR EXHIBITION.—Thursday, March 20, to Sunday, March 30, 1952, at Geneva. For further information, apply to the secretary of the exhibition, 1, Place du Lac, Geneva, Switzerland.

SECOND UNITED STATES INTERNATIONAL TRADE FAIR.—Saturday, March 22, to Sunday, April 6, 1952, at the Nay Pier, Chicago. Representative for the United Kingdom and Ireland: Mr. A. P. Wales, 12, St. George-street, London, W.1. (Telephone: MAYfair 4710.)

MANCHESTER BUILDING TRADES EXHIBITION.—Tuesday, March 25, to Saturday, April 5, 1952, at the City Hall, Deansgate, Manchester. Apply to Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester. (Telephone: Deansgate 6363), or to the London agent at 167, Oakhill-road, Putney, London, S.W.15. (Telephone: VANdyke 5635.)

FIRST SUPERVISING ELECTRICAL ENGINEERS NATIONAL EXHIBITION.—Friday and Saturday, March 28 and 29, 1952, at the Royal Horticultural Society's new hall, Greycoat-street, Westminster, London, S.W.1. For further information, apply to the conference secretary, Mr. P. A. Thorogood, 35, Gibbs-green, Edgware, Middlesex. See also page 266.

EXHIBITION OF BRITISH COMPONENTS, VALVES AND TEST GEAR FOR THE RADIO, TELEVISION, ELECTRONIC AND TELECOMMUNICATIONS INDUSTRIES.—Monday to Wednesday, April 7 to 9, 1952, at Grosvenor House, Park-lane, London, W.1. Organised by the Radio and Electronic Component Manufacturers' Federation, 22, Surrey-street, Strand, London, W.C.2. (Telephone: TEMple Bar 6740.)

SWISS INDUSTRIES FAIR.—Saturday, April 19, to Tuesday, April 29, 1952, at Basle. Apply to the Division Economique, Swiss Legation, 18, Montague-place, London, W.1. (Telephone: PADdington 0701.)

SYMPOSIUM ON DIAMOND DRILLING.—Monday, Tuesday and Wednesday, April 21, 22 and 23, 1952, at Johannesburg. Organised by the Chemical, Metallurgical and Mining Society of South Africa and the Diamond Research Laboratory. Apply to the director of the Laboratory, P.O. Box 916, Johannesburg.

ROYAL SANITARY INSTITUTE HEALTH CONGRESS.—Tuesday, April 22, to Friday, April 25, 1952, at Margate. Apply to the secretary, the Royal Sanitary Institute, 90, Buckingham Palace-road, Westminster, London, S.W.1. (Telephone: SLOane 5134.)

TELEVISION CONVENTION.—Monday, April 28, to Saturday, May 3, 1952, at Savoy-place, Victoria-embankment, London, W.C.2. Organised by the Radio Section of the Institution of Electrical Engineers. Apply to the secretary of the Institution at the address given above. (Telephone: TEMple Bar 7676.) See also pages 265 and 371, *ante*.

INTERNATIONAL FOUNDRY CONGRESS AND SHOW.—Thursday, May 1, to Wednesday, May 7, at Atlantic City, New Jersey, U.S.A. Organised by the American Foundrymen's Society, 616, South Michigan-avenue, Chicago 5, Illinois, U.S.A.

BRITISH INDUSTRIES FAIR.—Monday, May 5, to Friday, May 16, 1952, at Earl's Court, London, S.W.5, and Olympia, London, W.14; and Castle Bromwich, Birmingham. Particulars from the director, British Industries Fair, Board of Trade, Lacon House, Theobald's-road, London, W.C.1. (Telephone: CHAncery 4411); or the general manager, British Industries Fair, 95, New-street, Birmingham, 2. (Telephone: Midland 5021.)

INTERNATIONAL EXHIBITION OF ELECTRICAL APPLIANCES.—Tuesday, May 13, to Tuesday, May 27, 1952, at Bologna. Apply to the Ente Autonomo Fiera di Bologna, via Farina 6, Bologna.

SWEDISH INDUSTRIES FAIR.—Saturday, May 17, to Sunday, May 25, 1952, at Gothenburg. *Agents:* John E. Buck and Co., 47, Brewer-street, London, W.1. (Telephone: GERrard 7576.)

GERMAN EXHIBITION OF CHEMICAL APPARATUS.—Sunday, May 18, to Sunday, May 25, 1952, at Frankfurt-on-Main, Germany. Organisers: Dechema Deutsche Gesellschaft für Chemisches Apparatewesen E.V., Frankfurt.

ELECTRICAL ASSOCIATION FOR WOMEN, 27TH ANNUAL CONFERENCE.—Monday, May 19, to Saturday, May 24, 1952, at Scarborough. Apply to the director, the Electrical Association for Women, 35, Grosvenor-place, London, S.W.1. (Telephone: SLOane 0401.)

CANADIAN INTERNATIONAL TRADE FAIR.—Monday, June 2, to Friday, June 13, 1952, at Toronto. Apply to Miss M. A. Armstrong, Canadian Government Exhibition Commission, Canada House, Trafalgar-square, London, S.W.1. (Telephone: WHItehall 8701.)

MECHANICAL HANDLING EXHIBITION.—Wednesday, June 4, to Saturday, June 14, 1952, at Olympia, London, W.14. Apply to the exhibition organisers, Iliffe and Sons, Ltd., Dorset House, Stamford-street, London, S.E.1. (Telephone: WATerloo 3333.)

ROYAL AGRICULTURAL SHOW.—Tuesday, July 1, to Friday, July 4, 1952, at Newton Abbot. Organised by the Royal Agricultural Society of England, 16, Bedford-square, London, W.C.1. (Telephone: MUSeum 5905.)

WELDING DESIGN AND ENGINEERING SUMMER SCHOOL.—Wednesday, July 16, to Sunday, July 20; and Sunday, July 20, to Friday, July 25, at Ashorne Hill. Organised by the British Welding Research Association, 29, Park-crescent, London, W.1. (Telephone: LANgham 7485.)

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING, FOURTH INTERNATIONAL CONGRESS.—Monday, August 25, to Friday, August 29, 1952, at Cambridge. For further information, apply to the secretary of the Association, Swiss Federal Institute of Technology, Zürich, Switzerland.

SWISS FAIR, LAUSANNE.—Saturday, September 13, to Sunday, September 28, 1952, at Lausanne. For further information, apply to Comptoir Suisse, Place de la Riponne 5, Lausanne, Switzerland.

INTERNATIONAL MACHINE TOOL EXHIBITION.—Wednesday, September 17, to Saturday, October 4, 1952, at Olympia, London, W.14. Organised by the Machine Tool Trades Association, Victoria House, Southampton-row, London, W.C.1. (Telephone: HOLborn 4667.) See also page 51, *ante*.

ASLIB (ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX).—Friday, September 19, to Monday, September 22, 1952, Annual Conference at The Hayes, Swanwick, Derbyshire. Apply to the secretary of the Association, 4, Palace-gate, Kensington, London, W.8. (WEStern 6321.)

LABOUR NOTES.

CONCERN at the growing shortage of metals for industrial purposes is being expressed in many quarters. In the steel trade, both the unions and the employers' organisations have drawn attention to the problems caused by the shortage and are united in their criticism of the Government's expressed intention of re-introducing the old system of steel rationing. An editorial note in the December issue of *Man and Metal*, the official journal of the Iron and Steel Trades Confederation, stresses the opinion that there can be no question, under the circumstances of the present metals position, that there is a need to reimpose control over the distribution of iron and steel. The writer of the article states that, for reasons which are widely known, steel is again in short supply, although through no fault of the industry itself. As the essence of economy is the extent to which the best use is made of materials which are scarce, it is right and proper that the utmost use should be made of the limited supplies of steel available by guiding these supplies into those channels which will serve the national interest best.

The writer regards it as surprising and even disconcerting, however, to find that the new arrangements to be introduced by the Government will be the same as those in operation up to May, 1950. He comments that the intricate and complicated system of allocations, which, previously, were subjected to such a barrage of complaint and criticism, are to be put into effect once again and that no attempt appears to have been made at simplification. It may be mentioned that, as announced by the Minister of Supply, Mr. Duncan Sandys, on November 12, steel allocations will be resumed as from February 4, 1952. From that date no one will be permitted to acquire or use specified types of steel unless he possesses an official authorisation permitting him or his sub-contractors to do so. Retail sellers of iron and steel will require licences to obtain controlled types of steel for re-sale. Consumers will be allowed to purchase small amounts of steel ranging in quantity from two cwt. of alloy iron or steel up to one ton of forgings or heavy plates. An alternative scheme for steel rationing, which was put forward by some sections of the trade, appears to have been rejected by the Ministries concerned, on the ground that the old scheme could be reintroduced more easily than a new one.

Delays and, in some instances, stoppages caused to manufacturing programmes owing to the lack of raw materials were referred to at a meeting between Mr. Sandys and representatives of the Engineering Industries Association in London on December 20. According to a statement which was issued by the Association after the meeting, the deputation met Mr. Sandys to express the increasing concern of industry generally at the continued shortage of raw materials, especially of steel and non-ferrous metals. The deputation, which was led by Lord Davidson, the Association's President, and Mr. Arthur Keats, the chairman of the Midland region of the Association, informed the Minister that a questionnaire circulated in the Midlands showed that there was a dearth of certain types of steel in the country and that "a very careful analysis of the hundreds of replies received showed a general unanimity of opinion on this point."

Mr. Keats informed the Minister, the statement proceeds, that there was a definite feeling in the Midland area that emphasis had been given to steel output by tonnage rather than on selectivity, and that, in consequence, steel makers had been rolling heavier sections, as was evidenced by the fact that it was far easier to obtain heavier sections than lighter ones. The representatives of the Association pressed the Minister to grant a respite from the ban on the use of copper and zinc, pointing out that the period of grace allowed in the Order was too short. Mr. Sandys promised that a thorough investigation should be made into the various points raised by the Association.

The demands of engineering employees in railway workshops for a "substantial" increase in their wages were the subject of renewed discussions at a meeting between the two sides of the Railway Shopmen's National Council in London on December 20, but again without an agreement having been reached. It is understood that the latest offers made by the Railway Executive amounted to increases of 9*s*. 6*d*. a week for craftsmen and 8*s*. for labourers, equivalent to the 8 per cent. advances in wages granted to other railway employees, but the unions representing the shopmen have remained firm in their demands that these work-people shall receive not less than the 11*s*. a week increase recently conceded to employees in the general engineering industry. Representatives of these unions, the Confederation of Shipbuilding and Engineering Unions and the National Union of Railwaymen, comprise the trade-union side of the Railway Shopmen's National Council and appear to have decided that, in view of the failure of the two sides of the Council to agree to a settlement of the claims, the dispute should be referred to Sir Walter Monckton, the Minister of Labour, with a view to its submission to arbitration. About 130 000 employees are involved in this wage claim.

Many of the smaller and medium-sized manufacturing firms in Britain are being seriously affected by the present high death duties, in the view of the National Union of Manufacturers. In a memorandum submitted to Mr. R. A. Butler, the Chancellor of the Exchequer, on December 18, and published at the end of last week, the union makes an earnest appeal for the appointment by the Chancellor of an impartial committee to hold a public inquiry into the full effects of death duties on industry. The union considers that such an inquiry is the only satisfactory method of revealing the extent of the mischief being done by this form of taxation and the degree of easement which is required. In the opinion of the union, the prevailing high rate of death duties is having "a disastrous effect on a major part of British industry."

An investigation into this problem was carried out in July last by the then Chancellor of the Exchequer, in response to a previous request by the union for an inquiry, and the Board of Inland Revenue subsequently issued a report, in the form of a White Paper, in which it was stated that no case had come to light of any family business having to be broken up in order to provide the money required for death duties. The union claims, in its recent memorandum, that this report touched only the fringe of the real problem and that it was confined to those cases in which death had already occurred. The union contends that it is the threat of death duties which has the most far-reaching economic effect. In many cases, the whole, or a substantial part of a business has to be realised to provide in advance the necessary liquid resources outside the business for the eventual payment of death duties. In other instances, the developments of a business requiring increased working capital may be restricted by similar causes. It is suggested that even such evidence as was produced by the survey conducted by the Board of Inland Revenue appears to have been too lightly dismissed in the resulting White Paper, and that the proposals contained therein for avoiding the breaking-up of businesses have only limited possibilities under present-day conditions.

Among other examples of the adverse effect of death duties on small businesses, which have come to the notice of the union, is the case of a manufacturer who was compelled to sell his machinery to purchasers in the United States, in order to meet death duties. This resulted in the closing of the business, and the dismissal of the forty skilled craftsmen employed to run the undertaking, which had been engaged on the production of consumer goods for America. There can be but few instances of businesses owned by individuals or partnerships having sufficient liquid resources from which to meet the duties and the union suggests that it is a basic error to suppose that the case against excessive death duties can be conclusively proved or rebutted by means of statistics alone. "What is involved is an appreciation of the business man's position when he is faced with a prospective liability to death duties, which he must regard as a tax on the capital of his business."

The chairman of the National Coal Board, Sir Hubert Houldsworth, has sent an end-of-year message of thanks to the coal-mining industry for the "magnificent" results which have been attained by the industry during the past twelve months. Sir Hubert states that the output of saleable coal produced is likely to be about seven million tons more this year than during 1950. He refers to this as a splendid achievement and considers that it will materially help in preventing hardships in the home and in keeping British industry at work.

Saleable coal mined during the first 50 weeks of this year totalled 215,144,700 tons, of which 204,445,300 tons were deep-mined and 10,699,400 tons were open-cast, according to statistics issued by the Ministry of Fuel and Power on December 19. Comparative figures for the corresponding period last year show a total output of 209,452,600 tons, of which 197,553,000 tons were deep-mined and 11,899,600 tons were open-cast. Total stocks of coal distributed during the first 49 weeks of this year, ended December 8, amounted to 206,204,000 tons, of which 195,215,000 tons were used for inland consumption, 7,444,000 tons were exported overseas, and 3,545,000 tons were taken as bunkers. During the 49 weeks ended December 9, 1950, coal stocks distributed by the National Coal Board totalled 205,359,000 tons, comprising 188,925,000 tons for inland consumption, 12,610,000 tons sent overseas, and 3,824,000 tons taken as bunkers.

FUEL AND POWER PROJECTS.

Fig. 22. SIMPLIFIED SCHEME OF UNDERGROUND GASIFICATION EXPERIMENTS.

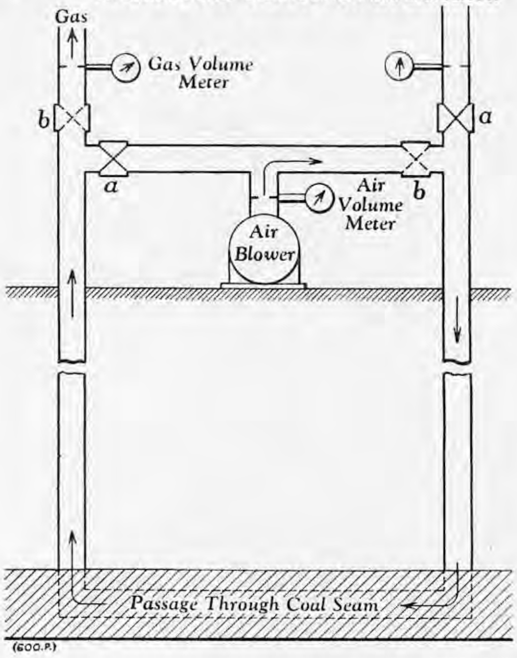


Fig. 23. 350-TON HORIZONTAL PEAT DEWATERING PRESS.

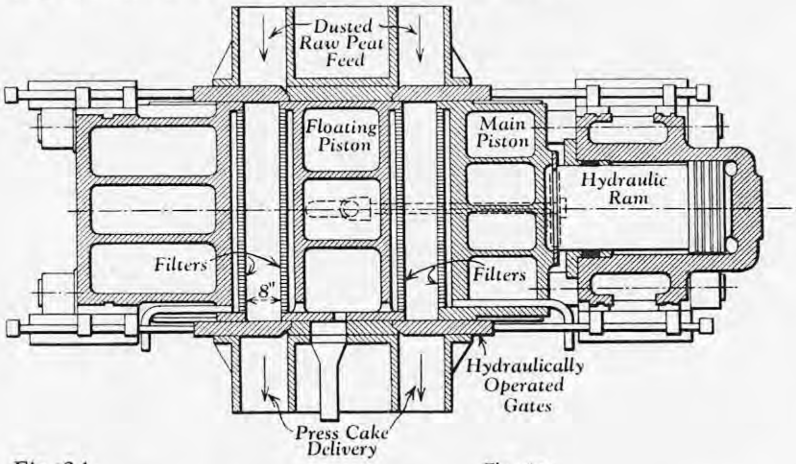


Fig. 25.

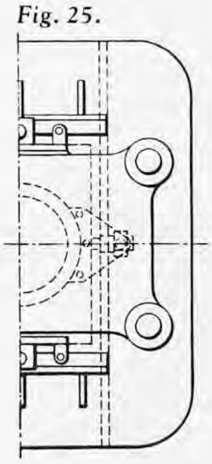
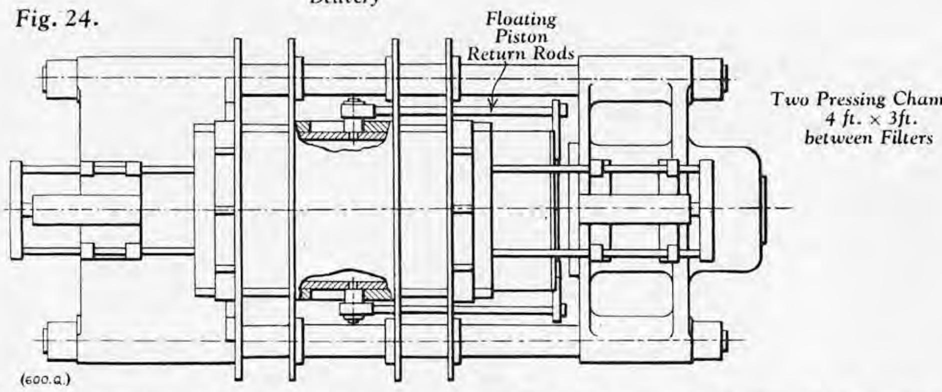


Fig. 24.



SOME FUEL AND POWER PROJECTS.*

By H. ROXBEE COX, Ph.D., B.Sc. (Eng.)

(Concluded from page 796.)

THE objective of the present British work on the underground gasification of coal is to discover whether it could be an economic commercial operation in Great Britain. Preliminary assessments, which included appreciation of foreign work, suggested that work in the field on an experimental scale, designed to provide data on which a dependable assessment of the economic prospects could be made, was justifiable and so the present programme was put in hand in 1949.

There were at the outset two main lines of study—the investigation of the gasification process and the quite separate investigation of methods of creating the system. These studies would be followed by consideration of the use of the energy. As, however, for the study of the gasification process in the field the creation of a system was an essential preliminary, a method was adopted which, though of considerable intrinsic interest, was recognised from the outset as of limited applicability. This method, involving horizontal drilling, was particularly suitable for the site at Newman Spinney, near Chesterfield, where work was started.

The first system was made by drilling two vertical holes, 4 in. diameter and 50 ft. apart, from high ground down to a wet banded coal seam about 75 ft. below the surface. Open-cast operations had produced an exposed face at a low level nearby, from which a roughly horizontal hole could be drilled to intersect in the seam with the verticals. This drilling work, so easily dismissed in a few words in this brief account, produced numerous problems of interest to engineers, quite apart from their relationship to underground gasification. In particular, new techniques for effecting intersection between vertical and horizontal drillings had to be developed. The vertical and horizontal drillings formed a U-tube, with its base in the coal. In July, 1950, the coal was ignited with Calor gas, and air was pumped down one vertical in such measure that the gasification reaction was maintained. The system, shown diagrammatically in Fig. 22, continued to produce gas until March, 1951, when it was closed down. Reversal of flow is obtained by opening the valve *a* and closing *b*, and vice versa (Fig. 22).

For the first ten weeks of gasification, the gas quality was maintained without any difficulty at an average of about 80 B.Th.U.'s per cubic foot, the only encouragement needed being occasional reversal of the direction of air flow when undue increase in upcast temperature or drop in gas quality suggested it. In other words, each vertical hole was in turn upcast and downtake. As the burnt-out space became wider, the tendency for some of the air to miss contact with the walls became evident in a lowering of the gas quality. Some encouraging experiments were done to overcome this, in which air was introduced at the side of the passage from an additional vertical. By this means, the quality of the gas was partly restored. The effects of variation in the frequency of flow reversal and in the rate of air supply were examined, and at one stage steam was introduced to see whether it would improve the gas quality. Its effect was, however, masked by the presence of a great deal of water in the seam.

During the initial ten-week period when the production of gas was most satisfactory, over 100 tons of coal were gasified with a total thermal yield of about 67 per cent., made up of some 49 per cent. as combustible gas, 11 per cent. as sensible heat, and 7 per cent. as steam. During this period, and the subsequent periods of deterioration and partial recovery, much valuable basic information was obtained. It was possible to begin to make elementary economic calculations which suggested the possibility of producing the gas in a full-scale system at between 1*d.* and 2*d.* per therm, rough figures substantially less than the probable revenue the gas could earn as a power producer—2½*d.* to 3*d.* per therm.

While these first trials of the combustion and gasification processes were running, a great deal of thought was being given to the problem of finding a more generally applicable way of making the underground system. The idea of a "mechanical mole," which had been investigated in Belgium, was seriously considered and the methods under development in oil fields for drilling curved holes were examined. The possibility of directional explosive charges was not overlooked. The most interesting possibility, however, seemed to be to make a passage by the application of pressure, which, it was suggested, would either open up natural fissures in the coal or lift the overburden and cause a crack above, below, or in the seam.

The first experiment to test this was with compressed air and was on a modest scale, the two verticals being only 33 ft. apart. Naturally, the compressed air tended to diffuse evenly round the downtake, but when the pressure exceeded that of the overburden—at about 100 lb. per square inch—the presence of the upcast made itself felt and it began to deliver about 20 per cent. of the air supplied. Ignition was achieved at this pressure by means of hydrogen, and gasification was maintained for some three weeks, by which time a drop in the required pressure showed that a connecting channel had been burnt through between the boreholes. Thereafter gas production continued at the usual low pressure. The three weeks at high pressure is obviously inconvenient and expensive (and would be more so with the much larger channels which would be required in practice) and effort is being directed, therefore, to pressure techniques in which this initial delay does not occur.

The initial work at Newman Spinney, though encouraging and full of interest, naturally left some important questions unanswered. The first was—how favourable or unfavourable is the site ? Certainly, the coal is poor in quality. It is half dirt, wet, containing 9 per cent. sulphur and is lying in thin layers. Clearly, experience with coal of different kinds is needed before a true assessment can be made. This is one of the reasons for seeking additional sites for experiment. Trials are in preparation at the first of these, in Worcestershire, where the coal and geological formation are substantially different from those at Newman Spinney. Another obvious problem was to find the optimum spacing of verticals and the best geometrical arrangements. Trials have begun at Newman Spinney with a second system, made by horizontal drilling, with verticals 75 ft. apart, which will throw some light on this. Trials on the same site are also being extended to a seam at 200 ft. depth. In this case, we hope to establish the system by high pressure and to operate on a larger scale than has yet been attempted in Great Britain.

The experiments so far have been confined to the study of the gasification process and the making of systems in flat seams. Utilisation of the gas produced does not appear to present serious difficulty, but is being carefully studied as part of the economic survey. There is no present intention of trying to make gas for domestic purposes or synthesis purposes ; the aim is industrial gas which may be burned in power stations on the underground gasification site.

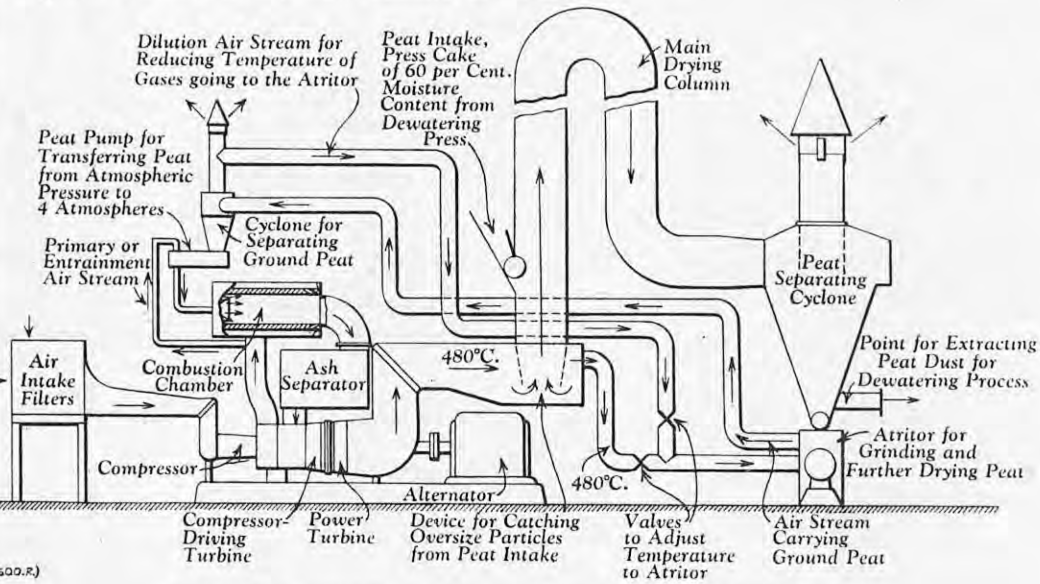
It is hoped that, in the next few months the work will have given enough information for an economic assessment to be made. If this is favourable, we should hope to check it by means of a pilot-scale system. Given success at that stage, it might be right to incur the heavy expense of a full-scale scheme. The possible prize—a large-scale addition to the national fuel resources—is so great that continued experiment, if necessary over a long period, appears to be fully justified.

By "total" gasification is meant the conversion of coal into gas with such completeness that the only other product is ash. In this sense, total gasification has long been practised, not only in the form of the gas-producer process but as the gasworks process of carbonisation with water-gas generation from the resultant coke. Other processes have been developed, notably in Germany, but only for brown coals. These and other methods as applied to British coals have been debated for some years, but a fresh review was made in the Ministry towards the end of 1949, which resulted in the sketch of an attractive picture, in which gasification of a wide range of the cheaper coals, near to their source of production, was associated with high-pressure transmission of the gas to the points of consumption. The subject was considered by the Scientific Advisory Council, who agreed with the need for more detailed investigation, and in 1950 a committee was formed under the chairmanship of Dr.

*** The 38th Thomas Hawksley Lecture, delivered to the Institution of Mechanical Engineers on Friday, November 16, 1951. Abridged.**

FUEL AND POWER PROJECTS.

Fig. 26. ARRANGEMENT OF PEAT-BURNING GAS TURBINE.



EXPERIMENTAL INDUSTRIAL TWO-STAGE CENTRIFUGAL COMPRESSOR.

Fig. 27.

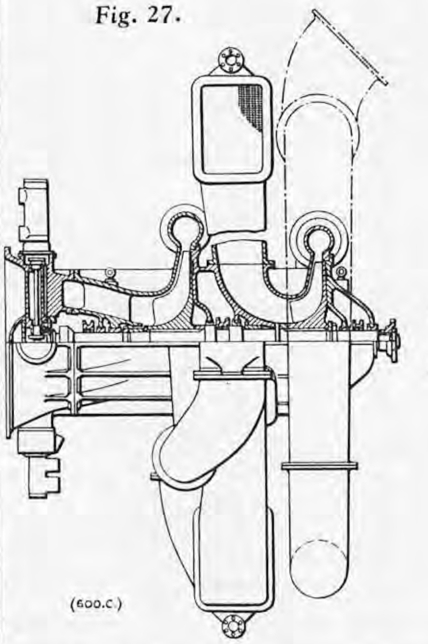
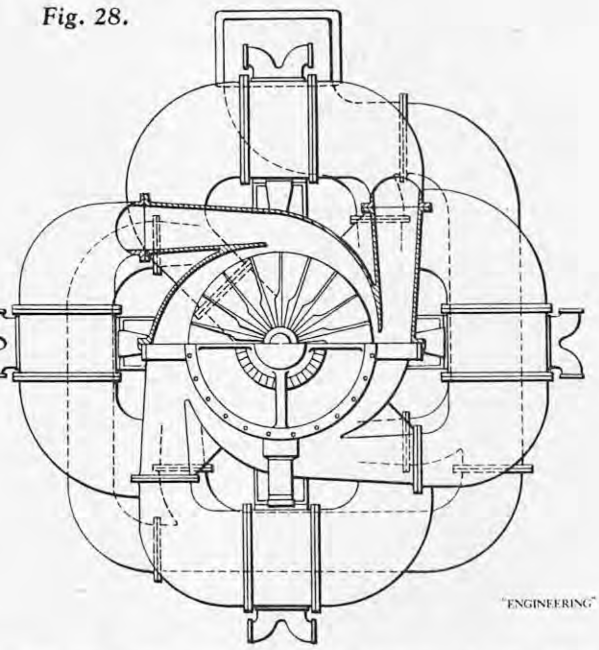


Fig. 28.



F. A. Williams to examine the subject of gasification and its associated problems and to report on what methods it thought most promising for a concentrated effort to evolve a commercial process.

The committee made an interim report in February, 1951, in which it advocated the adoption of the hydrogenation method of the Gas Research Board, integrated with the generation of electrical power from the hot gases and carbon residues from the gasification process. In other words, the committee had added an important feature to the picture—the idea, in the interests of maximum economy, of abandoning total gasification in favour of integrated gas and electricity production.

The suggested scheme permitted the use of cheap non-caking coals. It involved the treatment of coal with hydrogen under a pressure in the range of 25 to 50 atm. at a temperature of about 900 deg. C. (1,650 deg. F.). It was estimated that the gas could have a calorific value well above 500 B.Th.U. per cubic foot if desired. Being generated under pressure, the gas would be particularly suitable for transmission along high-pressure pipelines in a manner similar to that used for natural gas in the United States and for coke-oven gas in Germany, and, in general, the picture of a high-pressure country-wide gas grid, based on gasification of the cheaper coals in the coalfields, was given greater definition.

This lecture is a progress report. In the cases of some of the projects discussed, the "hardware" stage has been reached. In others, it is well advanced. In this case, we are only near the end of the "talking" stage. I have thought it worth while to discuss even this early stage, however, as the matter is one of prime importance. Not only does the scheme of high-pressure generation in the coalfields in association with a high-pressure grid transmission system represent a major change in the country's organisation, but the three great fuel and power industries—coal, gas, and electricity—are also all involved in it. Such a scheme must of necessity be considered with the greatest care, and only now are we nearing the point of an expanded experimental effort. The committee seem to have taken the matter as far as it can go without experiment on a considerable scale.

At this stage, the major uncertainty lies in the choice of the method to be used to prepare the hydrogen-rich gas demanded by the hydrogenation stage. Part of the residue from this stage could be employed and for this several methods, including the use of oxygen, are available. An alternative is to crack with steam part of the methane produced by hydrogenation. The committee have not been able to select a preferred method and my own view is that two or more will have to be tried in pilot plants before the best solution is found.

There are two programmes of peat utilisation work, one under the Secretary of State for Scotland and the other under the Minister of Fuel and Power. These two programmes have always been well co-ordinated. The Scottish programme is under the general direction of the Scottish Peat Committee, which was formed in 1949, and it includes work on peat winning as well as on the use of peat as a fuel. In the latter part of the programme are important experiments on the use of peat in gas turbines. The two gas-turbine programmes, Scottish and English, are, though co-ordinated, quite clearly differentiated, for the former is concerned with the closed cycle and the latter with the open cycle.

In Scotland, the work is being handled mainly by the North of Scotland Hydro-Electric Board, the ultimate users, and their contractors, John Brown and Company, Limited. The basic scheme is to burn peat in an air heater which can be used with the 500-h.p. John Brown gas turbine. This air heater is under construction. Behind the design and construction is a programme of experimental work which is well advanced on a test rig on which the powdering, drying, and combustion of peat is being studied.

One of the chief difficulties with peat has always been the need to dry it before use. As found, it is over 90 per cent. water and as normally burnt it is only 30 per cent. water. The usual air-drying processes are long and a great handicap. With the gas turbine, a radical change is hoped for from the use of mechanical methods to remove the larger part of the water, followed, in both the closed-cycle and open-cycle proposals, by further drying in the heat of the cycle.

The main work for the Ministry of Fuel and Power is being done by Ruston and Hornsby, Limited, of Lincoln, and stems directly from proposals made by C. H. Secord in 1948. The target is an adaptation of the well-known Ruston and Hornsby 3CT engine to peat burning. Calculation shows that this kind of engine should be able to take in peat at about 80 per cent. humidity and, by the use of its own heat, to dry the peat sufficiently for easy combustion. To reach even 80 per cent. from the original 90 per cent. is, however, not without difficulty.

In the drained bog, the peat contains about 9 lb. of water per pound of dry substance. About 7 lb. of the water is loosely held and may be separated mechanically, while the remaining 2 lb. is colloidally bonded and can only be removed by thermal or chemical means. The mechanical removal is made difficult by the fineness of the particles and, although it is possible to press out a large proportion of the water through a clean filter cloth, the time required is prohibitive and clogging of the filter soon takes place. Fortunately, a filtering process in which such troubles are avoided has been developed in Germany. This is the Madruck process, in which the raw peat is macerated into pieces of hazel-nut size and dusted with dry peat dust. This procedure allows nearly two-thirds of the water to be squeezed out separately—an 8-in. depth of dusted peat may be dewatered within 1 min. over filter slots $\frac{1}{2}$ mm. wide with a pressure of 30 atm. We are adapting this process to the highly humified Scottish peat, with the problem of doing it on a power-station scale in mind. A contract has been placed with John Shaw and Sons (Salford), Limited, for the prototype hydraulic press illustrated in Figs. 23 to 25, on page 823, and a small press on more conventional lines is being built for initial tests in Scotland.

About 6 lb. of water per pound of dry substance will be removed in these presses. This leaves $2\frac{1}{2}$ lb. more to be removed by evaporation to provide a dry powder of 30 per cent. humidity for combustion in the turbine. This evaporation will be done, in the first tests with the 3CT engine, due early in 1952, by a flash drier in the 480 deg. C. (896 deg. F.) exhaust flow from the turbine, as shown in Fig. 27. If the experiments with this simple cycle and the initial dewatering experiments are successful, we shall proceed to consider more elaborate cycles such as the ingenious proposal of C. H. Secord, in which the peat is dried under cycle pressure by gases at or near to turbine inlet temperature and the steam produced by drying, instead of passing to waste, passes with the products of combustion through the turbine. With this arrangement, the power/weight ratio of the plant is some five times that of the plain peat gas turbine, and very compact high-power plants become possible.

A considerable amount of work on combustion of peat has been done. Mr. T. F. Hurley, at the Fuel Research Station, has successfully burned peat in his "straight-through" chamber, on the design of which Ruston and Hornsby's first chamber is based. Their preliminary work has been mainly concerned with studying the combustion of 30 per cent. humidity peat in test combustion chambers fed with air from an old Power Jets W2/700 engine. Granulated peat has also been successfully burned in the B.C.U.R.A. slagging chamber. The general view is that the ash problem will prove much less difficult with peat than with coal. The ash content in peat does not exceed 5 per cent. and the ash itself is relatively soft.

The closed-cycle peat gas turbine, which is the target of the John Brown work, is likely to be a relatively large plant which would be sited on a large bog which should supply it with fuel for an extended period—at least 20 years. With the open-cycle type of plant there is the different possibility, which may have its advantages, of having relatively small (e.g., 5,000 kW) and relatively mobile plants which, when they have exhausted a local area of bog, can be moved simply to another site. In other words, the two kinds of plant may provide two kinds of operation—one in which the peat is brought to the power station and the other in which the power station is brought to the peat.

In all the gas turbines described above, and in the great majority of industrial gas turbines in the world, the compressors are of the axial kind. There is no doubt that the axial compressor is very efficient, but there is equally no doubt that the centrifugal compressor has stronger claims to consideration than its almost complete neglect suggests. The axial compressor is undeniably the more fragile and, in some applications of the gas turbine, robustness of construction throughout the machine is very desirable. Further, the centrifugal compressor should, except in large sizes, be the cheaper to construct. Despite these qualities, the centrifugal compressor would have no strong case if its efficiency were appreciably less than that of the axial; but, while the axial compressor is achieving efficiencies of and above 90 per cent., the centrifugal is, on one engine at least, the 1,000-h.p. Oerliken, achieving 85 per cent. This sort of difference will be acceptable in many circumstances if the robustness and cheapness are achieved.

For very small gas turbines, the axial compressor, with its tiny blades, so difficult to make and aerodynamically so far below the best, would be unsuitable. For large gas turbines, the centrifugal through its sheer size, and hence cost, looks less attractive than the axial which, in large sizes, is less open to the charge of fragility. At a guess, I put the upper limit of the centrifugal tentatively at 2,000 h.p.

The neglect of the centrifugal compressor is unwarranted, and its continued neglect may definitely hinder progress. Consequently, the Ministry of Fuel and Power has placed a contract with D. Napier and Son, Limited, for an experimental centrifugal compressor which will ultimately be fitted to the English Electric Company's coal-burning gas turbine. This is a two-stage centrifugal compressor (Figs. 28 and 29) in which as much as possible of the aerodynamic knowledge gained in the development of aircraft gas-turbine centrifugal compressors will be embodied. Moreover, the severe restrictions on size and weight in the aircraft gas-turbine will be absent. The main features are relatively low tip-speed, generous diffusion space, intercooling, and low entry Mach number. The compression ratio of 5 : 1 will be obtained with impeller tip speeds of about 1,100 ft. per second, a speed shown by tests on aircraft engine compressors to be near that for peak efficiency.* The compressor is designed for an air mass flow of 40 lb. per second at its full speed of 8,250 r.p.m. Intercooling is to be provided. This, in addition to giving a material increase in the efficiency of the gas turbine of which the compressor will form part, will give some control of the inter-stage matching during experimental running. The generous diffusers and the intercooling do lead to an overall diameter distressing to an aircraft engine designer—nearly 9 ft. for an impeller of only 2 ft. 6 in. diameter—but to restrict the geometry in any way for this experiment would have been foolish. The Mach number at the entry-vane tips will be about 0·68, compared with the approximation to unity occurring in most aircraft engines with centrifugal compressors.

The possibility of using wind power on a large scale has always been attractive, and, since the 1939-45 war, rising fuel costs and the shortage of power have made it more so. As a result, an investigation into the potentialities of wind-driven electricity generators was started early in 1948 under the aegis of a committee of the Electrical Research Association. The Ministry of Fuel and Power, the electrical supply authorities and interested industrial concerns were represented on this committee. Preliminary investigations suggested that, provided the scale were large enough, on windy sites it should be possible to produce electricity by this method at an economic price. From that point work branched out in three directions. First, a detailed survey was undertaken of wind behaviour over long periods at a number of likely places. This survey is still in progress and much valuable information has already come from it.

Secondly, contracts have been given for the building of pilot-scale wind-power generators, producing about 100 kW each on full load. The first of these generators, built for the North of Scotland Hydro-Electric Board, is now just starting to operate at a site in the Orkneys, where it is connected to the Diesel-powered system serving the island. The other windmill, being constructed for the British Electricity Authority, has a special pneumatic transmission system for transferring the power from the windmill shaft to the generator. This system, invented by J. Andreau of Paris, is of considerable interest. The windmill blades are hollow and their rotation centrifuges air along the blades and consequently draws it up the windmill tower, which is in the form of a hollow tube. The air flow drives a turbine connected to a generator at the bottom of the tower.

The third line of work, for which the Ministry took direct responsibility, has been the investigation, by means of a series of design and costing studies, of the variation in cost of electricity produced with the size and the type of windmill employed. The variations include not only tower design (e.g., reinforced concrete or open steelwork), but also the mechanism for transmitting energy to the generator (e.g., through mechanical gears, hydraulic systems, and the Andreau system described above). Preliminary results from this survey suggest that more economical production of electricity is possible as size goes up, at least to outputs of about 3 megawatts. This would mean very large windmills, with blades over 200 ft. in diameter and, for this size, erection costs are a major item. As a result, some consideration is being given to a new tower design in the form of a tripod of which one leg is pivoted to the ground, while the feet of the other two rotate on a circular track so that the windmill can keep into wind. The advantage of this design is that the whole apparatus can be assembled with the tower collapsed and then can be hoisted into position by a simple derrick mechanism.

Wind power is a practical possibility, and we are at the stage of exploring its economics by experiments in construction and, later, operation. Two most important steps forward have been taken in the two machines ordered by the supply authorities. It is not too soon to consider what the next step might be and, in this consideration, the tripod type, built to a size which would give reliable data on the cost of constructing and erecting large-size windmills, merits careful thought.

There are a few other matters which should, perhaps, be referred to. Some of them are matters which, if left unmentioned, would become the subjects of inquiry, as they clearly demand consideration from any organisation which is seeking to examine as many potentially useful ideas as possible. On tidal energy, we feel at present that, from the research or development point of view, there is nothing to be done. A great scheme, the Severn Barrage scheme, has been examined with great care and reported upon. It will shortly be studied further by means of a model by the Hydraulics Research Establishment. When general conditions are favourable to the carrying out of the scheme, it will be necessary to check its economics in relation to contemporary trends.

I receive a steady stream of letters on gathering the energy of moving water, particularly waves. There is, of course, nothing in the idea in the least wrong in principle. The difficulty is to discover a genuinely economic system. Though the energy is free, it is ill-conditioned; there is a strong tendency towards large apparatus transforming little energy. While, therefore, wave energy remains on the programme, we await the proposal which will throw a new economic complexion on it.

Another aspect of water power has, however, received some serious attention. This is the notion known usually as "pumped storage." The idea, in its simplest terms, is to use power-station energy during off-peak periods to pump water from a low to a high level. At peak periods, the water is allowed to flow down again through water turbines and so generate electrical power. The problem has no scientific or engineering facets—it is an economic problem. Is it cheaper to build the necessary hydraulic works, pumps, and water turbines or a new conventional power station ? Careful calculations suggested that pumped storage, of which there are several Continental examples, could, in certain circumstances, be the more economic choice.

Another fascinating possibility is to use the sun's energy. It has not, however, appeared to be sufficiently practical in Great Britain to stimulate any experiments here. There are, however, a few interesting possibilities to which we hope to devote attention later. One of these is the use as a fuel of sewage sludge. This would be a very wet fuel, as is peat. I do not expect that we shall feel justified in considering it further until we have gained a great deal more knowledge about the use of peat as a fuel. Another experimental study we hope to make is on the exploitation of shale in situ. This is an extension of our underground gasification work. We are also studying the fuel cell and examining the practicability of fuel crops.

By far the most significant of the possible new sources of energy, however, is nuclear fission. The necessary experimental information is being obtained. At this stage, it is not possible to say more than that a power station using an atomic source of energy will not necessarily be a less economic proposition than a power station of a conventional kind.

* In centrifugal-compressor jet-propulsion engines, tip speeds of 1,500 to 1,600 ft. per sec. are usual.

UNITED KINGDOM PRODUCTION OF IRON AND STEEL.—Statistics issued by the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1, indicate that steel production in this country, in November, was at an annual rate of 16,437,000 tons, compared with 15,629,000 tons in October and 17,472,000 tons in November, 1950. The output of pig iron was at an annual rate of 10,194,000 tons in November, against 9,865,000 tons in October and 10,042,000 tons in November, 1950.

SERVO MECHANISMS.*

By A. L. WHITELEY, D.Sc., M.I.E.E.

THE term "servo mechanism" is usually understood to mean an assembly of apparatus for obtaining accurate angular-position control of a more or less remote shaft. This review therefore covers electrical servo-mechanisms of the remote-position-control type, mainly for use in the Services; automatic regulator devices used in the electrical industry, mainly for voltage, speed, tension and position control; and some electrical devices for position control.

Remote position control servos of the last war embodied the items of apparatus shown in Table I.

TABLE I.

Function.	Hydraulic.	Electric.
Data transmission (e.g., director to to guns).	Magslips, Selsyns or equivalent devices.	Magslips, Selsyns or equivalent devices.
Initial amplification.	Hydraulic or electric.	Electric (usually electronic).
Final amplification.	Hydraulic pump (electric - motor drive).	Amplidyne or metadyne generator (electric - motor drive).
Final drive to mounting.	Hydraulic motor.	Direct-current motor.

These data apply mainly to anti-aircraft guns, some searchlights and the larger aerial mountings for radar, i.e., ½-h.p. drives and upwards. Stabilising methods, particularly of some hydraulic systems, were often in the nature of a compromise between that which was theoretically desirable and that which was deemed practical. Overall accuracy of aiming was sometimes achieved only by compensating for servo errors elsewhere in the system. A major advance in the last decade has been the design of mechanical assemblies specifically for servo control, with gearing of the highest quality, the avoidance of bevel and worm drives, if possible, and the elimination of irreversible-worm drives for anything but miniature or instrument-type units.

The conflicting requirements of mechanical rigidity and minimum weight of Service equipment remain, and are accentuated by the demands for still higher performance from servo mechanisms for following high-speed aircraft targets. It still appears to be the common practice to obtain position feedback, or reset, from a point in the drive as near to the driving motor as possible, thus avoiding resilience and backlash in the main gear train. Whilst this arrangement gives the maximum available stiffness of the servo system, errors in the power gearing are not compensated. A major contribution to the solution of this difficulty is "divided reset," in which the optimum values of reset from the motor shaft and final output-member to be positioned are combined. Stabilisation of large electrical remote-power-control systems operating with a suitably designed mechanical output end is no longer a problem; stabilisation by feedback alone is common, although there are few adherents to the principle of modifying the error signal to obtain approximations to its time derivatives.

Small servo mechanisms (having an output of 10 to 100 watts) are a very common requirement in fire-control apparatus, navigating systems and radar. Two types developed since 1939 are worth noting. The first is the Velodyne, which still has much to commend it when a medium-voltage direct-current supply is available. The other electric type still in use is one suitable for an alternating-current supply; operating with the usual Magslip or Selsyn data transmission, it comprises a relatively simple electronic amplifier which feeds one phase of a two-phase induction motor, the other phase being connected to the alternating-current supply in such a manner that the desired 90 deg. time-phase displacement is obtained. Stabilisation is not entirely straightforward, no ideal source of feedback electromotive force being readily available. Where supplies at 400 cycles and above are available, magnetic-amplifier-type servos are being used, particularly for low output powers; costs and weights are generally higher than those of the equivalent electronic methods.

As regards automatic regulators for industrial control, it is sometimes necessary to maintain approximately constant tension in a strip of material being unwound from a reel and fed into a processing device; and/or, after processing, constant-tension reel-up may also be required. A variable-speed electric reel-drive motor must compensate for the changing diameter of the coil, and it must also maintain material tension, within limits, during acceleration and deceleration of the system.

* A review of progress, published in the *Proceedings of the Institution of Electrical Engineers*, vol. 98, Part I, page 289 (1951). Abridged.

Such conditions exist in the cold reduction of metal strip in a rolling mill. As there is appreciable difficulty in the direct measurement of tension in heavy strip, the armature current of the reel motor is held constant, with suitable corrections to compensate for inertia during acceleration, and changing reel diameter. Rotating amplifiers, e.g. Amplidynes, have been used for this duty during the past decade, and magnetic amplifiers have been used to a limited extent recently. Tension is controlled to an accuracy of about $\pm$ 5 per cent. at strip speeds up to 6,000 ft. per minute, with reel-motor horse-powers up to 900.

Cold reduction of metallic strip is often carried out in a tandem mill, which consists of a succession (from two to five) of stands of rolls between which strip is held in tension. A principal requirement is that the speed relationship between different stands must be adjustable, and when once set the speed relationship must remain constant over a wide range of strip speed. During the last few years there has been a great increase in maximum speed and hence in the ratio between threading speed and maximum speed, the latter now being in the region of 6,000 ft. per minute. To meet these demands, the present practice is to supply the motor driving each stand from a separate generator, the voltage of which is controlled relative to a common reference potential.

For arc-furnace control the last few years have seen a pronounced movement towards the use of continuous regulators giving rapid action and freedom from overshoot. A present-day arrangement comprises an Amplidyne or Metadyne generator operating each electrode winch motor, the primary field of the rotating amplifier being controlled in response to arc current and voltage. Alternatively, electro-hydraulic control is being used. Tension contrôllers (and relative-speed controllers) for the rolling of aluminium sheet have been installed in recent years, using principles similar to those described for steel mills. Wiredrawing also may demand more accurate control of tension than that described above, and where very fine wires are handled, direct measurement and control of tension have been adopted.

The use of induction motors with dynamic braking for mine winders has greatly increased in the last decade. Under dynamic braking conditions, direct-current is applied to the motor stator, and the generated alternating current power developed by the rotor is dissipated in a loading resistor. During retardation, the frequency of the generated alternating current varies over a wide range, and to avoid instability a number of installations have recently been provided with an automatic regulator system maintaining a constant voltage/frequency ratio at the motor slip-rings. Rotating amplifiers, or alternatively magnetic amplifiers, are being used to control the direct-current excitation of a motor to maintain the optimum voltage/frequency ratio.

A high degree of accuracy ($\pm 0 \cdot 03$ to $\pm 0 \cdot 1$ per cent.) of relative speed between sections is necessary on paper-making machines. Speed regulators have been introduced in which the output voltage of a tachometer generator (one per section) is compared with an adjustable portion of a common reference voltage. The error voltage thereby produced is fed to an electronic or electronic-amplidyne regulator system. Recent practice is to use a direct-current generator for each section direct-current motor, the field of each generator being controlled by its respective regulator system. In the printing industry, close speed control is not necessary in connection with the electric drives for a rotary press, but a related requirement, namely, wide speed range, arises because of the necessity of inching and smooth running at, say, 1 to 2 per cent. of the top speed of the press. Two motors have commonly been used to cover this wide range, and another alternative is a variable-speed alternating-current commutator motor with a separate automatic regulator operating the motor brush-gear. A recent development is the use of an electronic (ignitron) rectifier and direct-current motor; feedback is readily provided and automatic phase control of the ignitron rectifiers gives the 100 to 1 speed range. Automatic register control is being used to a limited extent on multi-colour rotary printing presses.

In general, the textile industry has not been a notable user of variable-speed drives which require close automatic control. It is conceivable that recognition of the versatility of electric drives will encourage the increased use of electric control of sequencing operations. A modern type of stocking-knitting machine is an example of this; during the knitting cycle, the machine is operated over periods of varying duration at different predetermined speeds. A speed range of about 10 to 1 is required, e.g., bottom speed for welt-turning, through various intermediate speeds, to top speeds for knitting the calf. Alternating current commutator motors with hydraulic regulating-gear have been used, but a more recent and more precise control comprises electronic/direct-current motor drive with feedback and stabilising to ensure wide speed range, close speed control at any one setting, and smooth acceleration and deceleration.

A variable-speed drive is a common requirement in the machine-tool industry; conventional Ward Leonard drive, alternating current brush-shifting commutator motors, and pole-changing induction motors are frequently used. The relatively narrow speed range or somewhat poor performance at low speeds is generally tolerated. However, there has been a greater acceptance of electronic control (controlled rectifier and direct-current motor), feedback of direct-current motor voltage being used to obtain good speed regulation, or—what is more important in practice—wide speed range, 10 to 1 and up to 50 to 1 sometimes being required. Position-control servos have found one of their few industrial applications as attachments to lathes for automatic profiling.

In the power-generation field, vibratory, carbon-pile, and quiescent types of rheostatic regulator are still commonly used for generator voltage control; there has been no marked change in performance characteristics or methods of application in recent years. There has been a noticeable tendency towards a more continuous-control type of regulator, and the following three types have appeared in recent years. One is the electronic regulator, one form of which comprises a hard-valve pre-amplifier with a thyratron rectifier supplying controlled direct-current to the conventional main exciter. There is also the rotating-machine-type regulator (Amplidyne or Metadyne), which generally supplies excitation to the main exciter and has a non-linear ferromagnetic circuit to provide the error signal. In a third type, a magnetic amplifier is added to the second type, the output of the amplifier exciting the rotating-amplifier field. Again a non-linear ferromagnetic circuit provides the error signal.

The almost universal method of measuring angular deviation between two remote shafts is by electrical machines known variously as Magslips, Selsyns, Autosyns, in which the electrical output is fed to an all-electric system, or is used to control an electrical pre-amplifier with subsequent hydraulic amplification and actuation of the power-driven remote shaft. While Selsyns were available commercially before the 1939-45 war, modifications were made to improve accuracy for military and naval purposes; improvements in winding technique during the early part of the war resulted in a pair of Selsyn-type units, weighing 13·5 lb. each, having an average combined accuracy of $\pm 0 \cdot 1$ deg. The widely used 2-in. Magslips (2 lb. each) had a combined accuracy of $\pm 0 \cdot 5$ deg. Post-war progress in this field can be recorded, a commercial development having resulted in units of 5 oz. each with a combined accuracy of approximately $\pm 0 \cdot 8$ deg., and appreciably better accuracy than this can be achieved by coding and selecting of machines.

Electrical information of angular velocity is often required in connection with the stabilising of remote-power-control systems; in general, high accuracy is not required for this duty, and small permanent-magnet direct-current machines are commercially available. When an alternating current signal is essential, the drag-cup type of machine is available, which gives a fixed-frequency signal proportional to speed, with phase reversal on reversal of rotation. High accuracy and consistency of speed indication are industrial rather than Service requirements, a particular example being the control of a paper-machine sectional-drive.

A great variety of means of detecting departure of an electrical quantity from a desired value are known. It is often sufficient, however, to compare the electrical quantity with a reference source and to excite a machine or other amplifying device with the difference, thereby obtaining an error signal. A requirement, therefore, is a stable but adjustable source of reference voltage or current. A recent development in this connection is a voltage or current standard derived from a permanent magnet. For electronic circuits, the best-known voltage reference is a glow-discharge tube with an appropriate gas filling, giving consistency to within about 0·2 per cent. over fair periods. The requirement of a non-electronic reference with a very long-term stability of 0·2 per cent., or better, still remains. Non-linear resistance or non-linear ferromagnetic elements in bridge arrangement are used increasingly for detecting departure of voltage from a predetermined level.

A great variety of electronic amplifiers, including vacuum valves, thyratrons, ignitrons and, occasionally, multi-anode grid-controlled rectifiers, have also been incorporated into both industrial and Service equipment. The availability of high-gain, virtually instantaneous response, and high input-impedance have provided a strong case for their greatly increased use. Complex stabilising feedback networks, and circuits for obtaining time derivatives and integrals of error tend to be cumbersome and sometimes impractical without an electronic amplifier. The still-persistent and understandable argument against the electronic valve is life—mainly on the grounds of unpredictable failure, rather than average life expectancy. While conservatively rated valves in correctly designed equipment give much longer lives than is commonly supposed, it cannot be recorded that there have been any major steps in this country to ensure longer life expectancy and reduced risk of premature failure. Heating time, especially of the higher-power mercury-vapour triodes (thyratrons) and restricted temperature range, both of the said valves and the mercury-pool types, can be limiting factors. In this connection, a promising valve development of the last few years is the use of xenon gas-filling for thyratrons; this results in a heating time of about 30 seconds and the temperature range is adequate for tropical or arctic conditions. These thyratrons are now available in this country at ratings up to 6·4 amperes average anode current.

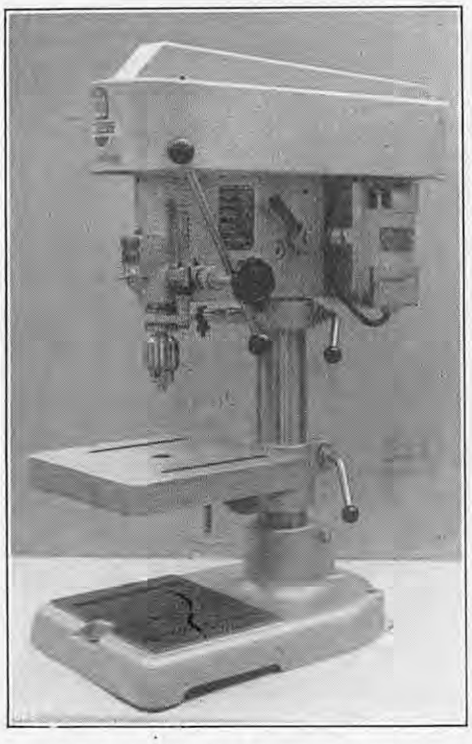
A brief cost-and-performance summary of the various types of magnetic amplifier would be misleading. It is necessary to bear in mind that, compared with electronic methods, rotating-machine amplifiers, magnetic amplifiers and various types of contact-making and vibratory devices may necessitate increased costs elsewhere in the system. Metering elements and feedback stabilising circuits will generally be more costly and sometimes less effective with non-electronic amplification. A material consideration in favour of rotating-machine amplifiers is that the output current and voltages are reversible, whereas magnetic, electronic and other amplifiers may necessitate some duplication of apparatus to obtain a similar effect; furthermore, the energy storage due to machine rotation can be a determining factor in favour of the rotating amplifier as the final amplifying element.

The recognition of the necessity for design and manufacture of gear assemblies with good rigidity and high overall quality specially for remote-position-control servo mechanisms during the past ten years or so is probably more important than the detail improvements in gear-cutting which have been effected in the same period. Nevertheless, improvements in manufacture have been made, and increased capacity in Great Britain for accurate gear-cutting is worth noting. Cumulative tooth-pitch error and backlash are the main defects to be minimised. For lightly-loaded gear trains used in data transmission, etc., it is common practice to use split spring-loaded anti-backlash wheels. Maximum cumulative tooth-pitch error of a gearwheel is a doubtful quantity, being difficult or impossible to measure on every unit under production conditions; the following figures are therefore offered as a guide, and actual results depend much upon individual skill, care in setting up, etc. The maximum cumulative tooth-pitch error of small instrument-type gears (of about 3 in. diameter) can be about 0·0004 in., with a probability of error of a mating pair of wheels of about one minute of arc. Improvements in design and construction of hobbing machines for large gears, say up to 100 in. diameter, permit guarantees to be made of cumulative tooth-pitch error not greater than 0·0017 in. and pitch-to-pitch errors of about one-tenth of this figure. These are optimum figures for gears cut under temperature-controlled factory conditions; allowance for wear and distortion in service, and for backlash, depend upon the application.

The provision of spring-loaded friction clutches designed to slip at a certain overload torque is common practice in electric remote power-control systems. Until recently, clutches have played only this somewhat secondary role in servo-mechanism design. The magnetic-fluid clutch usually consists of two concentric magnetic cylinders separated by a small radial gap, the cylinders being rigidly attached to independent shafts. The radial gap is filled with a finely divided iron powder in a light oil. A magnetic coil is so disposed as to produce a magnetic flux in the gap; when magnetised the fluid increases its viscosity, and with a high flux-density it apparently solidifies. Since the torque the clutch can transmit is to a fair approximation proportional to the magnetising current, its use in a position-control servo mechanism is apparent. For example, two contra-rotating power shafts can be clutched to an output shaft by two magnetic clutches which are differentially energised in response to a servo-mechanism error signal. The power-amplification factor of the clutch is several hundred. Appreciable attention is being paid to this new device, but applications are being limited by two difficulties. First, the iron-oil mixture causes locking of the two clutch members, since the iron particles separate out after standing idle for a few hours; and secondly, the problem of preventing the magnetic powder from reaching shaft bearings does not appear to be completely solved; magnetic traps are being used with some success. Because the majority of remote-position-control servo mechanisms must function for lengthy periods at low output-shaft velocities against appreciable torque, any clutch device must operate with continual slip and, consequently, appreciable dissipation of energy in the form of heat. It is, therefore, not apparent that the magnetic-clutch servo mechanism is a serious competitor with other known methods for ratings above, say, $\frac{1}{2}$ h.p.

BENCH AND FLOOR DRILLING MACHINES.

Two sturdy multiple-purpose drilling machines have been introduced recently by the Startrite Engineering Company, Limited, Waterside Works, Gads Hill, Gillingham, Kent. The accompanying illustration shows the SP 160 bench machine; the other, SP 161, has an identical adjustable head unit, but is provided with a 60-in. column, instead of a 30-in. column, and a larger baseplate for ground mounting. The drilling capacity of the new machines is ½-in. diameter, and four drilling speeds are provided—480, 1,020, 1,990, and 4,220 r.p.m. The spindle is adjustable vertically over 3¼ in. The working table, which can be tilted through 90 deg., is 11½ in. by 10 in., and the maximum distance between the chuck and the table is 10½ in. in the bench machine and 40½ in. in the floor machine. In both, the bases also are provided with working surfaces.



The spindle is driven by a ¼-h.p. motor, mounted vertically at the rear of the head unit, through a V-belt and four-step pulley drive enclosed within the head. The tension on the belt is automatically maintained at a constant value by a spring-loaded regulator; to change the driving speed, the pulley guard can be swung clear and the belt tension can be released by a cam-operated lever. Six splines are cut on the steel spindle in the driving part, and power is transmitted through a broached phosphor-bronze insert. The spindle is supported in a ground quill carrying one ball thrust bearing and two ball journal bearings. The spindle pulley is also carried in two heavy ball bearings which absorb the thrust from the horizontal belt drive. Vertical adjustment is provided by a feed rack, cut from the solid quill, which engages with a pinion actuated by the ball-handled lever. Wear of the quill can be compensated by adjusting a phosphor-bronze pad by means of a knurled knob. A depth gauge, graduated in English and metric units, is provided; the depth of the spindle feed can be pre-set by adjustable collars. A Jacobs chuck with a capacity range from $\frac{5}{64}$ in. to ½ in. is integrally mounted in the spindle. For quick return, a balance spring is provided, the tension of which can be varied.

The table, which is machined and has slots for holding the work, can be tilted through 90 degrees, and can be positively located in the horizontal, vertical, and 45-deg. positions. The table can be swung to one side when it is desired to accommodate deeper work on the base-plate, which is also machined and slotted. A tool tray is supported on the tubular column, serving also as a safety device to prevent the head unit from falling if the operator should forget to lock it after adjustment. In addition to the standard fittings supplied with the machines, there are also available a mortising attachment, a No. 1 Morse taper spindle, a machine vice, and lighting equipment.

INQUIRY INTO LOSS OF S.S. "FRED BORCHARD."—The formal investigation into the foundering and total loss of the s.s. Fred Borchard has been fixed for hearing at the Royal Courts of Justice, Strand, London, W.C.2, on Monday, January 7, 1952, at 10.30 a.m.

ANNUALS AND REFERENCE BOOKS.

Jane's All the World's Aircraft 1951-52.—The 1951-52 edition of "Jane's," the most comprehensive of all aeronautical reference books, has been thoroughly revised since last year, and follows the well-established pattern; it is divided into five sections, the first of which, Part A, is concerned with military aviation. It gives particulars of the air staff, organisation and bases, and equipment of the air forces of the world, excepting the U.S.S.R. Part B, which deals with civil aviation, opens with a description of the various international organisations, followed by a list of world and international speed, height and distance records. The main part of the second section gives particulars of civil-aviation administration, associations, flying clubs, publications, transport companies, etc., arranged alphabetically. Under the publications of Great Britain, an error has crept in concerning the price of the volume itself, which is stated to be three guineas whereas, in fact, it is four guineas. Probably those connected with the aircraft industry are interested principally in Part C, "All the World's Aeroplanes" (293 pages), and Part D, "All the World's Aero-Engines" (80 pages). These two sections are corrected up to July 31, 1951, but at the beginning of the book there are photographs and notes of aircraft and engines which have become available for publication between the end of July and the end of September. In Parts C and D, which are divided alphabetically under countries and subdivided alphabetically under constructors, brief notes are given on the history of each firm, and particulars of the construction and performance of their aeroplanes and engines which are in service or under development; in some cases, specifications of projected aircraft are also given. An index is provided at the beginning of each part. Excellent photographs and, in the case of aeroplanes, small general-arrangement drawings are included. The particulars given of Russian aircraft are sparse, but it is hoped to present reliable data on the MiG 15 in the next edition Finally, three pages are devoted to "The World's Airships"; this section was reintroduced last year and contains illustrated examples from Great Britain, France, the Soviet Union and the United States. *All the World's Aircraft* is excellent value and is an indispensable general and technical reference book for the aeronautical professions. It is compiled by Leonard Bridgman and published by Sampson Low, Marston and Company, Limited, 25, Gilbert-street, London, W 1.

Directory of Railway Officials and Year Book, 1951-1952.—The compilers of this useful reference book never allow it to stand still; the statistics and the names of the holders of office require confirmation or amendment for every new issue, and this work appears to be carried out thoroughly. The principal re-arrangement for this, the 57th year of publication, is the second stage in changing the method of presenting the various units of British nationalised transport. The order of the statistical and year-book information has been arranged in a more logical sequence. A new loading diagram for British main-line passenger rolling stock has been added, also a statement giving a list of countries which adhere to right-hand and left-hand running, respectively, on their railways, and a review of train accidents in Great Britain in 1949. Information received from Japan for the first time since the war has been included, and the Embassy of the U.S.S.R. in London has replied to the compilers' inquiries but without giving any recent statistics. The book is published by the Tothill Press, Limited, 33, Tothill-street, London, S.W.1, at the price of 40*s*.

Newnes Engineer's Reference Book.—Reference books are not built in one edition, any more than Rome was built in a day. Mr. F. J. Camm, the editor of this engineer's reference book, added 300 pages to the third edition, and for the present, fourth, edition he has added another 120 pages, arising largely out of suggestions made by readers. The result is a useful work, not, as a whole, better than or superseding older-established books of a similar kind, but to some extent complementary, since the proportion of space devoted to processes and other practical branches of engineering is greater than is usual. Thus, for example, there are chapters on lathe work, grinding, milling, surface broaching, drilling, planing, shaping, reaming, sawing, riveting, panel beating, pressing, founding, die-casting, die-sinking, wire-drawing, heat treatment, plastics, polishing and buffing, electroplating, soldering and welding, as well as others on production control, time and motion study, quality control, works cost accounts and wage incentive plans. There are, of course, the usual tables of screw sizes, etc., and the fundamental theories of thermodynamics and hydraulics are treated. Chapters not always found in such books are those on drawing-office practice and on patents, designs and trade marks. It is, however, on practical engineering matters that Mr. Camm's editorial policy is strongest, and if this feature can be improved and reinforced in subsequent editions, even at the expense of the chapters on theoretical subjects, the book will achieve a respected status. It is published by George Newnes, Limited, Tower House, Southampton-street, Strand, London, W.C.2, at the price of 50*s*. net.

Fire Protection and Accident Prevention Year Book, 1952.—The 12th edition of this annual, which is compiled by Mr. Geoffrey F. D. Pratt and published by Benn Brothers, Limited, Bouverie House, Fleet-street, London, E.C.4, provides a detailed index to the municipal and county fire-fighting resources in the British Isles, and those of the principal industrial undertakings which maintain private services. Information is also given about the most important brigades in the British Commonwealth. The legal sections are contributed by Mr. Peter Pain, M.A., and the summary of fire-fighting data has been revised by Mr. Wallace E. Whitehouse, M.B.E., M.Sc. At the end there is a diary section; and, of course, the usual reference directory to suppliers of equipment is retained. The price of the book is 10*s*. 6*d*., including postage.

BOOKS RECEIVED.

Measurement of Productivity: Applications and Limitations. Issued by the Joint Committee of the Institute of Cost and Works Accountants and the Institution of Production Engineers. Gee and Company (Publishers), Limited, 27-28, Basinghall-street, London, E.C.2. [Price 2*s*., post free.]

Ministry of Fuel and Power. Statistical Digest 1950. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 15*s*. net.]

Department of Scientific and Industrial Research. Report of the Radio Research Board with the Report of the Director of Radio Research for the Year 1950. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s*. 9*d*. net.]

Jane's All the World's Aircraft 1951-52. Compiled and edited by LEONARD BRIDGMAN. Sampson Low, Marston and Company, Limited, 25, Gilbert-street, London, W.1. [Price 4 guineas.]

Jane's Fighting Ships 1951-52. Edited by RAYMOND V. B. BLACKMAN. Sampson Low, Marston and Company, Limited, 25, Gilbert-street, London, W.1. [Price 4 guineas.]

Westminster Chamber of Commerce. Year Book for 1951. Offices of the Chamber, 2-3, Duke-street, St. James's, London, S.W.1. [Gratis.]

Industrial Diamond Trade Names Index for 1951-52. N.A.G. Press, Limited, 226, Latymer-court, Hammersmith, London, W.6. [Price 3*s*. 6*d*.]

Mechanical World Year Book, 1952. Emmott and Company, Limited, 31, King-street West, Manchester, 3. [Price 3*s*. 6*d*. net.]

Portugal. Ministério das Obras Públicas. Laboratório de Engenharia Civil. Publication No. 14. *Developpement et Problèmes de la Mécanique du Sol*. By R. HAEFELI. [Price 20 escudos.] No. 15. *Emprego da Ardosia como Material de Construção*. By A. V. GARCIA. [Price 40 escudos.] No. 16. *La Compressibilité des Sols*. By R. HAEFELI. [Price 20 escudos.] No. 17. *Notes sur la Résistance au Cisaillement des Sols Argileux*. By R. HAEFELI. [Price 20 escudos.] Nos. 18. *Photographic Method for Model Analysis of Structures*. By M. M. ROCHA and J. F. BORGES. [Price 20 escudos.] Laboratório de Engenharia Civil, Av. Rovisco Pais, 41, Lisbon, Portugal.

Portugal. Ministério das Obras Públicas. Laboratório de Engenharia Civil. Especificações E1-1951. *Vocabulario de Estradas e Aeródromos*. Laboratorio de Engenharia Civil, Av. Rovisco Pais, 41, Lisbon, Portugal. [Price 35 escudos.]

Melbourne and Metropolitan Tramways Board. Report and Statement of Accounts for the Year Ended 30th June, 1951. Offices of the Board, 616-622, Little Collins-street, Melbourne, Australia.

Road Research. Note No. 11. *Binder Distributors for Surface Dressing*. By D. B. WATERS and W. L. RUSSELL. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s*. 6*d*. net.]

Irrigation Engineering. Vol. I. Agricultural and Hydrological Phases. By IVAN E. HOUK. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 9 dols.]; and Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 72*s*. net.]

Fault Calculations. By C. H. W. LACKEY. Oliver and Boyd, Limited, Tweeddale Court, Edinburgh, 1. [Price 30*s*. net.]

The Modern Factory. By EDWARD D. MILLS. The Architectural Press, 13, Queen Anne's Gate, London, S.W.1. [Price 30*s*. net.]

Werkstattbücher No. 29. *Einbau und Wartung der Wälzlager*. By DIPL.-ING. WILHELM JÜRGENSMEYER. Second revised edition. Springer-Verlag, Reichpietschufer 20, Berlin W.35, Germany. [Price 3·60 D.M.]

Die Hebezeuge. By PROFESSOR HELLMUT ERNST. Vol. II. *Winden und Krane*. Friedr. Vieweg und Sohn, Braunschweig, Germany. [Price 38·80 D.M.]

NOTES ON NEW BOOKS.

Thermostats and Temperature-Regulating Instruments.

By R. GRIFFITHS. Charles Griffin and Company, Limited, 42, Drury-lane, London, W.C.2. [Price 20s. net.]

MANY ingenious methods have been developed for controlling the temperature of industrial and other processes, and, in recent years, their number and variety have been greatly increased by developments in electronics and in the design of servo systems. In this, the third, edition of his book, the author has included some account of these more recent developments as well as dealing with the older forms of control device, most of which are still regularly employed. The greater part of the book is descriptive, dealing with specific instruments or types of instrument, and methods of using them, the classification being broadly according to the form of sensitive element employed. In most cases the descriptions are supplemented by diagrams, sectional drawings and occasionally half-tone illustrations, all of which are of excellent quality. Besides the descriptive matter, there are a few chapters on special subjects, such as the accurate control of room temperature, the design of bimetallic strip regulators and the various types of heat exchanger. An appendix contains a highly condensed account of some analytical theories of temperature control which, the author remarks, are not yet sufficiently comprehensive for a final discussion to be given. This chapter requires to be read in conjunction with the theoretical papers listed as references. Similar lists of references are appended to each chapter, but few of these are to papers subsequent to 1943, the date of the previous edition of the book, and none, so far as has been observed, to work later than 1947. The book can be recommended as giving a clear account of the methods of temperature regulation.

Engineering Thermodynamics.

By PROFESSOR HERMAN J. STOEVER. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16. [Price 5·75 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 46s. net.]

THERE are now so many text-books on thermodynamics for engineering students that any newcomer needs to be of special merit to justify its appearance. The present work, from the pen of the professor of mechanical engineering at the Iowa State College, covers the usual ground of elementary books of its kind. It is confined entirely to "classical" thermodynamics, except for a brief explanation of gaseous pressure as being due to molecular bombardment. The book is divided into three parts, of which the first two deal, respectively, with the first and second laws of thermodynamics, and the third with the theoretical principles of steam and internal-combustion plants, refrigeration, compressors and air-conditioning. The latter subject is treated much more fully than is usual in British text-books. What extent of knowledge and intelligence the student is expected to possess is difficult to decide. It is taken for granted throughout the book that he is familiar with the symbols and operations of the calculus, yet the author assumes he needs many almost infantile pictures of imaginary apparatus in order to understand that, for example, a gas does work when expanding against pressure. It is, however, only fair to say that the greater part of the text is well above this level, and gives a clear and sensible exposition of the subject. A praiseworthy feature is the repeated insistence on the fact that the area of a theoretical indicator diagram ($\int P\, d\, V$) only truly represents the work that would be done if the process, whether adiabatic, isothermal or otherwise, were to be carried out in an ideally perfect reversible manner—a condition which is ignored by so many writers of text-books. In discussing the flow of saturated steam through nozzles, the author adheres to the obsolete theory that the steam expands under conditions of perfect thermal equilibrium, which leads to a critical pressure-ratio of 0·58 and to a discharge notably less than is found actually to occur in practice. Several pages later, he does mention the possibility of the steam being in a supersaturated state at the throat; and, to take account of this, he then advises the reader to design a nozzle under the assumption that the steam behaves like a perfect gas. This does not help at all; the question is, what index of expansion should be used? The advice should have been to assume that the steam expands as if superheated, with an index of 1·3, the critical pressure-ratio then working out to 0·545. Altogether, there are more than 500 problems for the student appended to the ends of the various sections, a few being fully worked out and most of the rest having their answers attached.

Measurement of Productivity: Applications and Limitations.

By the Joint Committee of the Institute of Cost and Works Accountants and the Institution of Production Engineers. Sole distributors: Gee and Company (Publishers), Limited, 27-28, Basinghall-street, London, E.C.2. [Price 2s., including postage.]

ALTHOUGH different in scope, this report may be usefully studied in association with Mr. A. W. Willsmore's *Modern Production Control*, reviewed below. The Joint Committee on the Measurement of Productivity contained some of the most experienced production engineers in the British engineering industry. Comparatively early in their inquiry, which began at the end of 1948, they found a notable lack of factual knowledge regarding the extent to which individual machines were actually used, and of statistical information (including costing data) available at supervisory level. The present report, after discussing productivity in general, and the methods of measuring it, makes certain recommendations on these and allied matters, adding two valuable appendices, one on "Machine Utilisation" and the other on "Presentation of Information at Supervisory Level." While much that they contain is or should be obvious, there are probably few works executives who would not derive some useful hint from a study of them.

Modern Production Control.

By A. W. WILLSMORE. Second edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 15s. net.]

WHEN the first edition of this book appeared, towards the end of 1946, it attracted favourable comment from a number of reviewers whose interest in it originated for quite different reasons. Our own comments on it, in our issue of March 28, 1947, were that it was "eminently sane and well-written"; and we drew attention, among other details, to the author's useful examples of how to combine the production of a variety of articles, which individually would be dealt with normally in batches, so as to obtain advantage, in production, from their aggregate volume. A new instance of what Mr. Willsmore describes as "a novel compromise between batch and flow production practices," in use in Sweden, is one of the principal new features in this second edition. The other new section of special note is a chapter on "Scheduling," much of which is devoted to a consideration of the pros and cons of establishing a detailed system for this purpose or, alternatively, employing a "progress chaser." In this, of course, much depends on the type of product, and a great deal on the type of progress chaser. Mr. Willsmore's views should be found of interest, even by those who may disagree with them.

The "M.E." Lathe Manual.

By EDGAR T. WESTBURY. Percival Marshall and Company, Limited, 23, Great Queen-street, London, W.C.2. [Price 12s. 6d. net.]

THIS is a book for the happy man who uses a small lathe for the fun of it. If he has only recently realised the model engineer's ambition to own a lathe, he is probably under the delusion that all his production problems are now solved; but Mr. Westbury's 160 pages—covering only the essential principles and practice—will go a long way towards instructing him in the art of turning and the adaptation of a lathe to milling, slotting, drilling, etc. The book is better bought before a lathe, however, as the early chapters give guidance on the recognition of those features in lathe design that are essential for model engineering, distinguishing them from those that are proper to other types of lathes. The remaining chapters deal with the foundations of lathe work: the forms of cutting tools, turning between centres, the use of the chuck and faceplate, boring, screwcutting, etc., as well as with lathe accessories. An appendix consists of screwcutting and other tables. There are numerous half-tone illustrations and sufficient line drawings for the purpose.

Quartz Vibrators and Their Applications.

By DR. P. VIGOUREUX and C. F. BOOTH. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 30s. net, postage 10d.]

THE piezo-electric effect was discovered in 1880, but does not appear to have found any application until 1918, when it was employed by Langevin in an apparatus devised for depth-sounding, directional underwater-signalling and detecting submerged objects, such as submarines. It is interesting to note that the generation and detection of ultrasonic vibrations by the aid of piezo-electric transducers continues to be one of the most important applications of the latter. For instance, the detection of flaws in engineering materials by ultrasonic methods is now a familiar technique. More recently, quartz crystals have found uses in the delay-line storage systems of electronic calculating machines and in determination of the elastic constants of engineering materials. After 1918, interest in piezo-electricity increased rapidly. In the following year, Nicholson published the results of his experiments with Rochelle salt and, in 1921, Cady described one of the most important present-day applications of quartz vibrators, namely, to frequency control. During the succeeding period up to the start of the recent war, the great advances which were made in radio-communication were accompanied by a corresponding extension of the use of piezo-electric aids in the stabilisation of radio transmitters, the control of master oscillators and the production of wave filters for multi-channel communication systems. Finally, during the war years, quartz vibrators had an enormous field of application to frequency-control in radio signalling. Between 1938 and 1948, for example, the annual production of finished crystal units rose from 10,000 to 1,500,000. The present volume, by two leading authorities on the subject, is based on an earlier book by Dr. Vigoureux, entitled *Quartz Oscillators and Resonators*, the second edition of which appeared in 1939. The earlier volume has now been largely re-written in order to bring it up to date. It remains primarily an account—and an excellent one at that—of quartz, its piezo-electric properties and its many applications, but in view of the widespread demand for quartz vibrators, a description of the methods employed in the manufacture of quartz units, the examination and selection of raw quartz, the bulk production of quartz elements, and their mounting, ageing and testing has been added. The book is issued under the auspices of the Department of Scientific and Industrial Research.

END OF THE ONE HUNDRED AND SEVENTY-SECOND VOLUME.