RECUPERATIVE HEAT EXCHANGER FOR GAS TURBINES.

In 1946, the firm of Heat Exchangers, Ltd., 53, Haymarket, London S.W.1—a subsidiary of the Superheater Company—was formed to examine, by theoretical and practical study, the various types of heat exchangers, particularly the tubular, plate, regenerative and pebble types. Numerous applications of these four types have been examined and particular attention has been paid to their possible use in connection with gas-turbines. A theoretical study of contra-flow primary-surface heat-exchangers showed that, to meet a given specification, the total heating surface required for a recuperator is practically constant, the face area, that is, the area of the matrix normal to the flow, is almost constant, being independent of the passage diameter, and the space occupied by the heating surface is mainly dependent on the passage diameter to which it is approximately proportional. Therefore, for minimum space an exchanger tends towards a unit of relatively large face area and short length, while the volume occupied by the end connections and headers is mainly dependent on the matrix-face area and thus is very nearly constant. The indications are that reduction of passage diameter is also the principal means of reducing weight, but for a tubular heat exchanger, the cost of tubing increases rapidly with decreasing diameter, so that progressive reduction in volume produces a rapidly increasing cost. For a plate-type heat exchanger, however, the cost of the material for the matrix is not so dependent on passage diameter; this, of course, represents a distinct advantage. As a result of this theoretical study, the company decided to devote particular attention to plate-type exchangers, and finally evolved the design shown in the drawings reproduced in Figs. 1, 2 and 3, on this page.

The prototype unit has been designed for a thermal recovery of 50 per cent., a total pressure loss of 1·5 per cent., and a mass flow of 1·25 lb. per second at each side. This, it is claimed, simulates the conditions for a unit having a thermal recovery of 75 per cent., but with a total pressure loss of from 4 to 6 per cent. As will be seen from Figs. 1, 2 and 3, the matrix is made up from elements each consisting of two corrugated plates welded together to form a series of parallel passages. These elements form passages for the high-pressure air and they are stacked one upon the other with the "crests" of the corrugations touching, thereby making a further series of external passages between the elements and parallel to those for the high-pressure air. The ends of the plates are pressed out in the form shown in Fig. 4, on this page, so that when two plates are welded together, they form a cowl. The shape of this cowl is a distinctive feature of the design as the cross-sectional area throughout is equal to that of the passages in the corrugated section, thereby eliminating aerodynamic expansion and contraction losses. The form of the cowl will be clear from Fig. 5, on this page, which shows two plates welded together to form a single element.

At the part where the cowl merges into the corrugations, it extends the full width of the element but is shallower than the corrugated portion; at the extremities, however, it is narrower but of the same depth as the corrugations. When the elements are stacked one upon the other, therefore, the cowls make contact with each other at their extremities, but, owing to the tapering cross-section, leave triangular-shaped spaces between adjacent cowls through which the heated gases pass into the external passages formed between the elements; pure counter-flow is achieved, therefore, without restricting or sensibly changing the direction of flow either of the gases or the high-pressure air. Alternatively both fluids could flow in the same direction when it is required to restrict the temperature of the metal in heat exchangers of low thermal recovery.

In general, the construction of the unit is quite straightforward. The two sheets forming a single element are identical and each is pressed from a single piece of 18-gauge deep-drawing bright mild-steel strip to form eight corrugations and two half cowls. Two sheets forming an element are then placed face to face after which they are spot welded along the roots of adjacent corrugations and seam-welded round the edges, the pressings being designed so that, when held together, internal passages having a diameter of $\frac{3}{16}$ in. are formed. To give internal stiffening, three tapered channel sections are spot welded to the inside of each cowl, the stiffeners being disposed in such a manner that they also form flow distributors. It may be mentioned here that all resistance welding was carried out under the supervision of the British Welding Research Association at the research department of British Insulated Callender's Cables, Limited. As the width of the corrugations necessitated the use of an electrode of less than standard diameter, preliminary tests were carried out to determine the strength of the welds, for which purpose the elements were subjected to an internal hydraulic pressure of 140 lb. per square inch. The results were good, as no failure occurred in any one of 16,000 spot welds. After pressure testing, the completed elements were acetylene welded into bundles of ten and loose flanges were fitted for joining to the headers. It should, perhaps, be mentioned here that mild steel was chosen for the prototype unit purely for ease of fabrication, it having been realised from the outset that it is not the best material.

The headers were designed to offer the minimum resistance to the flow of the exhaust gases, but at the same time to occupy the shortest possible space. Like the cowls, each header is fitted with three stiffeners, which also act as flow distributors. As the casing which supports the complete matrix is not subjected to any pressure loads, it is of comparatively light construction. The supporting structure comprises two side members built up from mild-steel angle sections, the two members being joined to each other along the lower edge by T-sections, the latter acting as supports for the matrix. The base is closed by sheet-steel plates which form a permanent part of the structure, the sides and top being covered by removable panels. Some idea of the construction of the casing can be formed from Figs. 12 and 13, on Plate XXXV, the former illustration showing the complete unit as

Fig. 1. SECTIONAL ELEVATION ON A-A

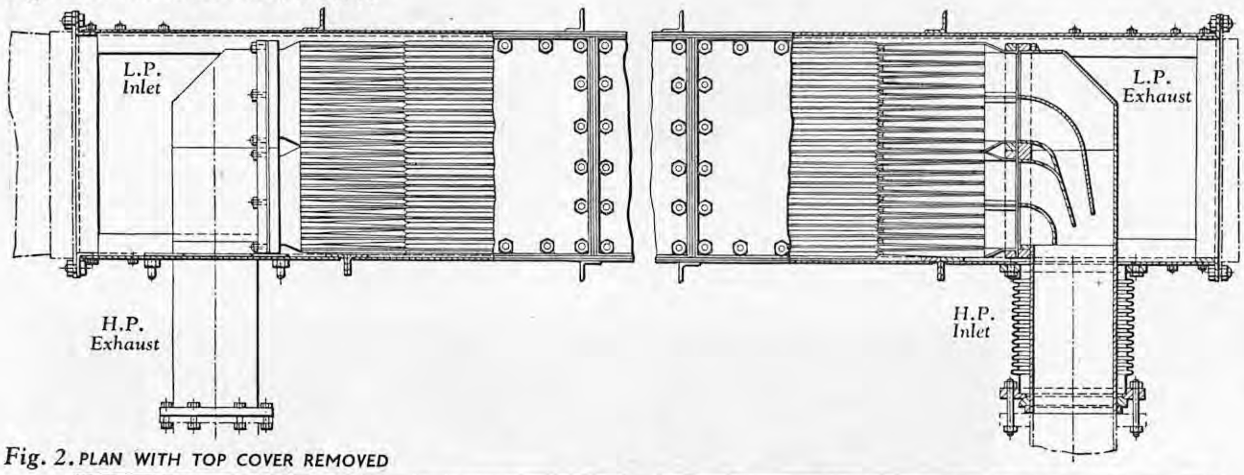


Fig. 3. END ELEVATION

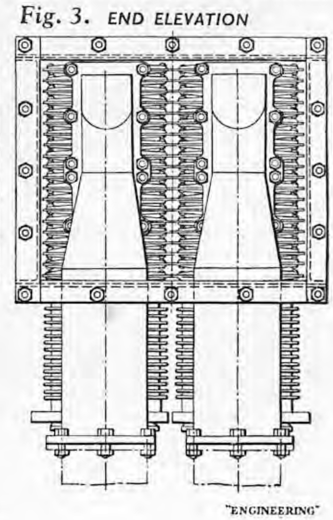
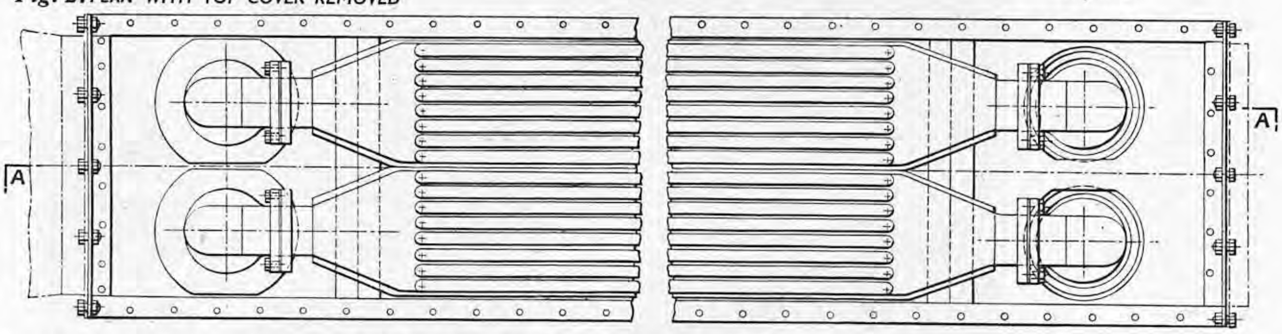


Fig. 2. PLAN WITH TOP COVER REMOVED



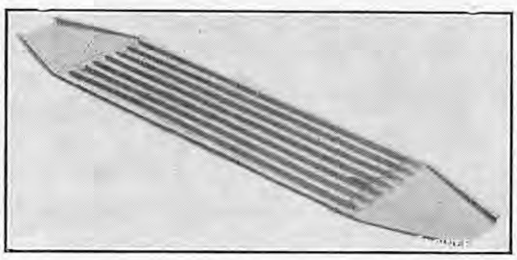


Fig. 4. Corrugated Plate Ready for Welding.

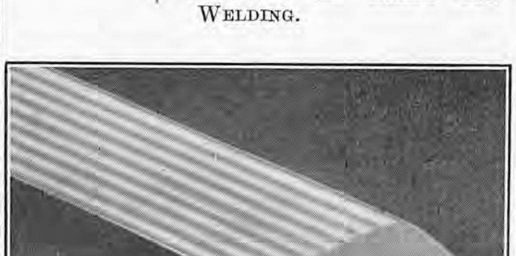


Fig. 5. Two Plates Welded Together to Form an Element.

RECUPERATIVE HEAT EXCHANGER FOR GAS TURBINES.

HEAT EXCHANGERS, LIMITED, LONDON.

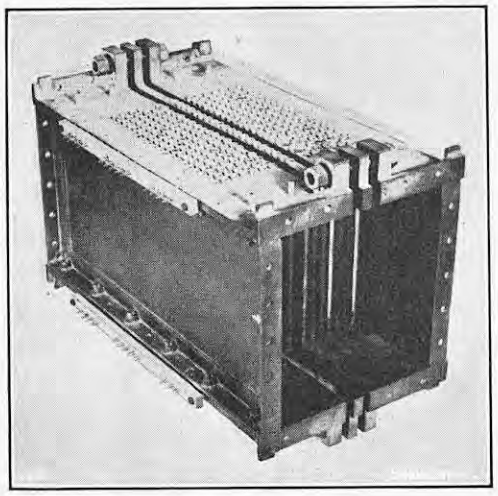


FIG. 6.

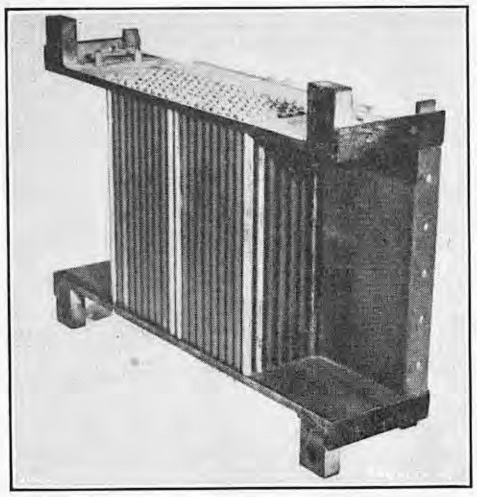


FIG. 7.

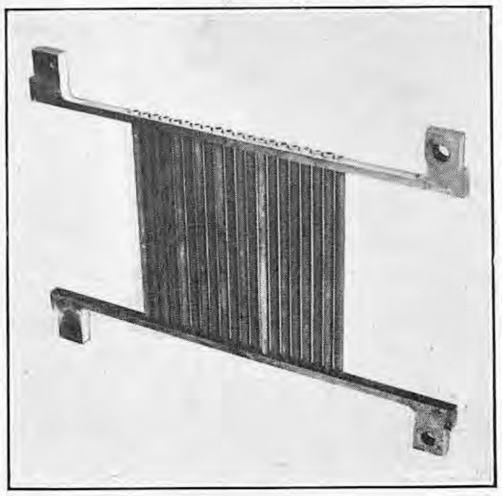


FIG. 8.

FIGS. 6, 7 and 8. TEST RIG FOR DETERMINING EFFECT OF DEPOSITS ON DIFFERENT MATERIALS.

arranged for testing with five of the six side panels removed and the latter the casing structure in the area of one set of headers. The casing is, of course, lagged, 3-in. thick mattresses composed of 85 per cent. magnesia being used for this purpose. Differential expansion between the matrix and the casing is allowed for by fitting stainless-steel bellows to the inlet headers, while transverse expansion is covered by allowing sufficient clearance between the casing and the matrix.

Accessibility has received careful attention, and when it is required to dismantle the unit for any purpose it is only necessary to disconnect the high-pressure pipes, unbolt the headers from the casing and remove the detachable top cover, after which each stack of elements, together with its headers, can be lifted out of the casing. If further dismantling is required, the headers can be unbolted from the elements thereby separating them into small bundles; there are ten elements to a bundle in the design under consideration. Cleaning can be carried out either by dismantling and immersing the elements in a solvent solution or by using cleaning rods with the elements *in situ*. If the fouling is not too severe, a washing solvent supplied under pressure through cleaning nozzles may suffice, but immersion in a solvent solution obviously will give the best results.

The questions of deposits, suitable materials and methods of cleaning have received careful attention by the Shell Petroleum Company, Limited, with whom Heat Exchangers, Limited, have been collaborating. At their research laboratories, the Shell Petroleum Company have an experimental tube bundle fired with the products from heavy fuel oil combustion. The tube bundle was constructed by Heat Exchangers, Limited, and is substantially a two-pass cross-flow heat exchanger. The construction will be clear from the photographs reproduced in Figs. 6 to 8, on this page, Fig. 6 showing the different parts in their relative positions, but not bolted "hard up," while Figs. 7 and 8 show one half of the assembly and the removable row of tubes, respectively. This form of construction, of course, permits several different types of tube to be examined with the minimum of trouble. Gases from a combustion chamber designed to burn both distillate and residual fuels pass directly across the tube bundle and those tubes adjacent to the removable row are fitted with thermocouples in such a way that the surface of the tube presents a smooth circumference to the gases.

Development tests of the prototype have come under two main headings, namely, basic research on models to determine the principles of design and full-scale work on the prototype unit under actual operating conditions. For the model tests, water was used as the working fluid, the flow being adjusted to give the appropriate Reynolds

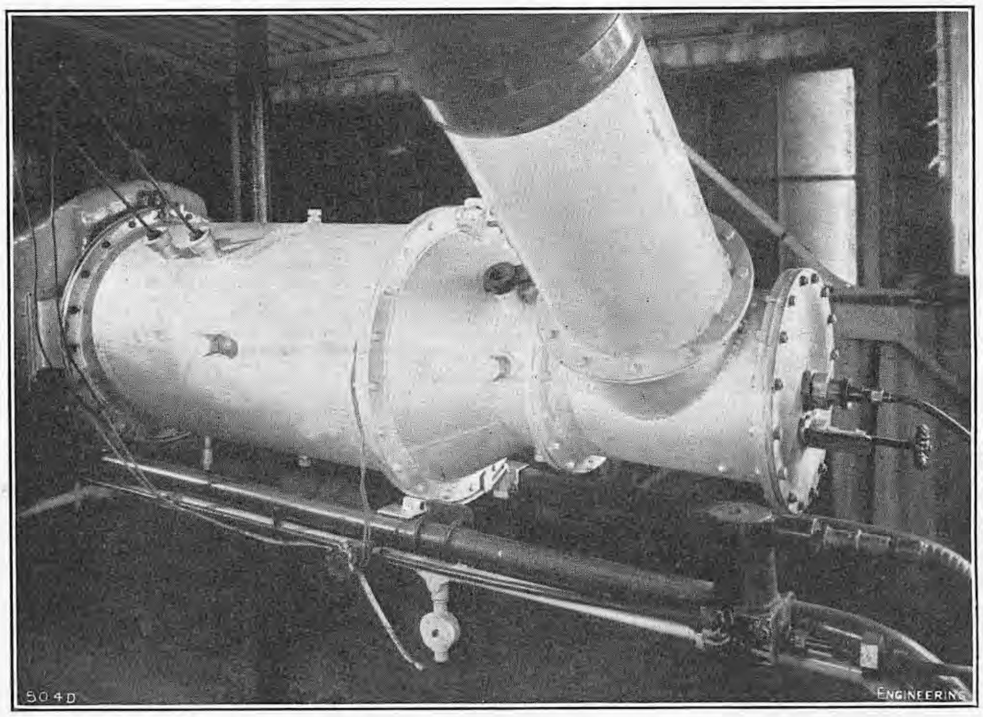


FIG. 9. LOW-PRESSURE COMBUSTION CHAMBER.

number, with full-size models of the prototype elements. A simple test rig comprising a pump, tanks, flow meter and test section was constructed for the purpose and so far, the work carried out has been directed towards obtaining internal and external pressure-drop figures and the distribution of flow, both internally and externally. The internal pressure drop was measured for various flows and lengths of corrugated section; by this means, the individual pressure drops through the corrugated sections and the cowls were determined, together with their variation with flow. The internal distribution was measured by collecting separately the flow through each passage and was found to vary considerably with the length of corrugated section. In order to assess the external distribution, the technique of photographing aluminium particles suspended in water was adopted, wooden models being used in a tank fitted with a transparent cover. Numerous photographs were obtained which, in addition to giving assurance as regards the section finally adopted, revealed profitable fields of research for even further reduction of pressure losses.

Full-scale tests on the prototype have been divided into two parts, namely, an investigation of flow distribution as a check on the model tests and as an indication of distortion of the matrix, and the establishment of performance against design. Internal distribution was measured by traversing a Pitot tube across the discharge from the inlet headers, the matrix and the outlet headers, and the distribution ascertained by this method proved to be uniform. Outside distribution at the end of the corrugated portion was measured by traversing a hypodermic tube between adjacent elements, the tube being drilled with a radial hole facing upstream; the tube is shown in position in Fig. 17, on Plate XXXVI. As a result of the readings obtained by this method, it was concluded that distortion of the matrix should not be caused by poor flow distribution. As a further check, however, routine measurements are taken at the end of every run of the position of a series of centre-punch marks in the matrix from a datum point. It may be mentioned here that provision has been made in later designs to permit individual longitudinal expansion of each bundle of elements in the event of unequal temperature distribution at the inlet to the unit.

For the performance tests, the plant illustrated in Figs. 10 and 11, on Plate XXXV, and Figs. 14 and 15, on Plate XXXVI, was constructed. It has been designed to supply two counter-flowing fluids, one

(To face page 450.)

RECUPERATIVE HEAT EXCHANGER FOR GAS TURBINES.

HEAT EXCHANGERS, LIMITED, LONDON.

(*For Description, see Page* 449.)

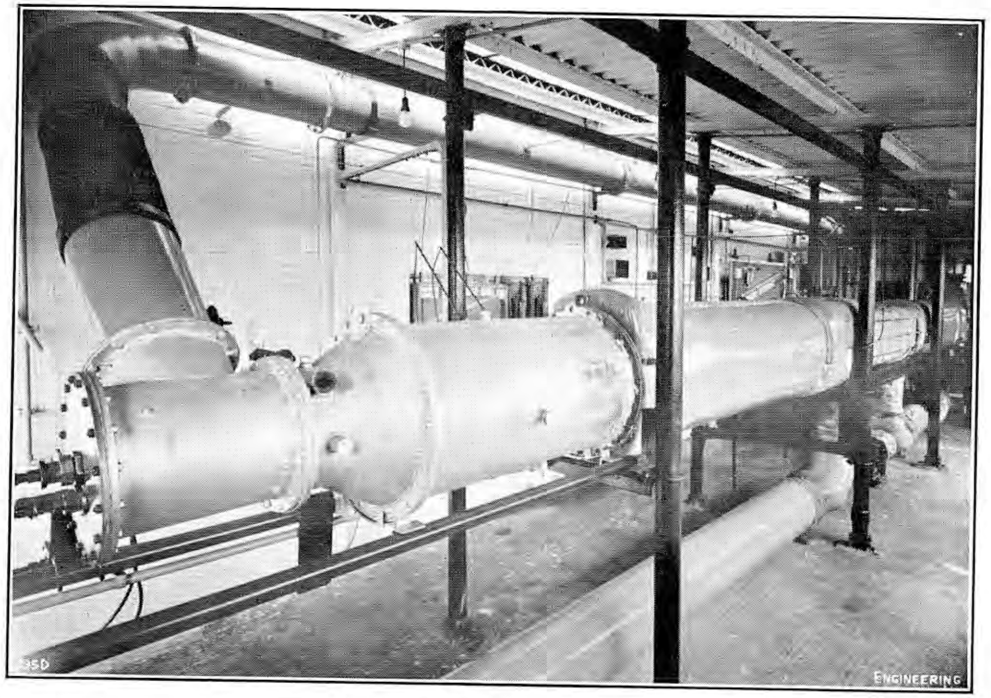


FIG. 10.

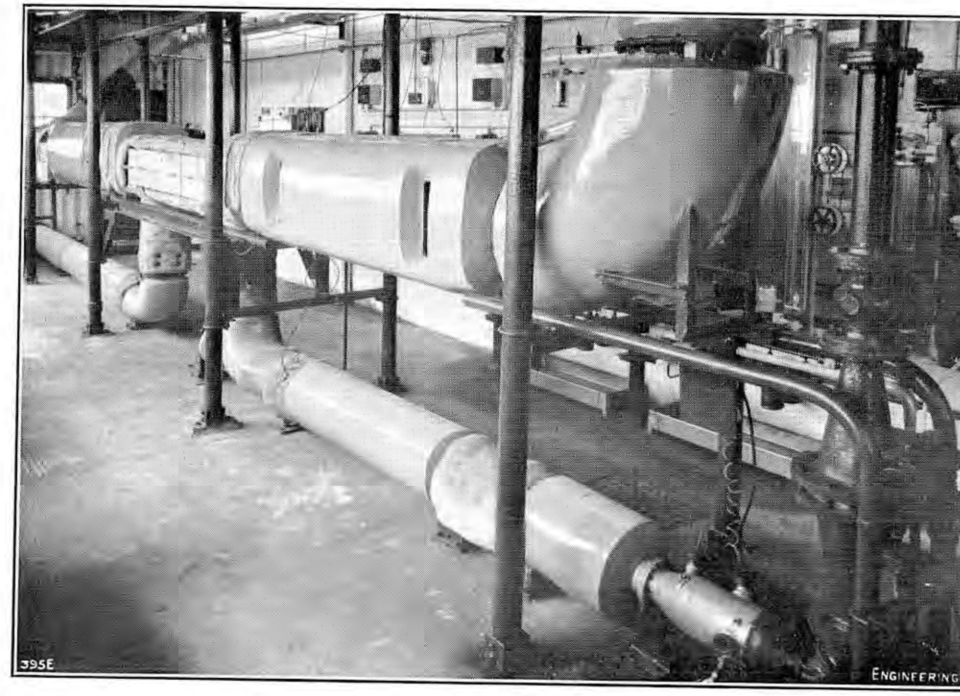


FIG. 11.

FIGS. 10 AND 11. FULL-SCALE PLANT FOR PERFORMANCE TESTS.

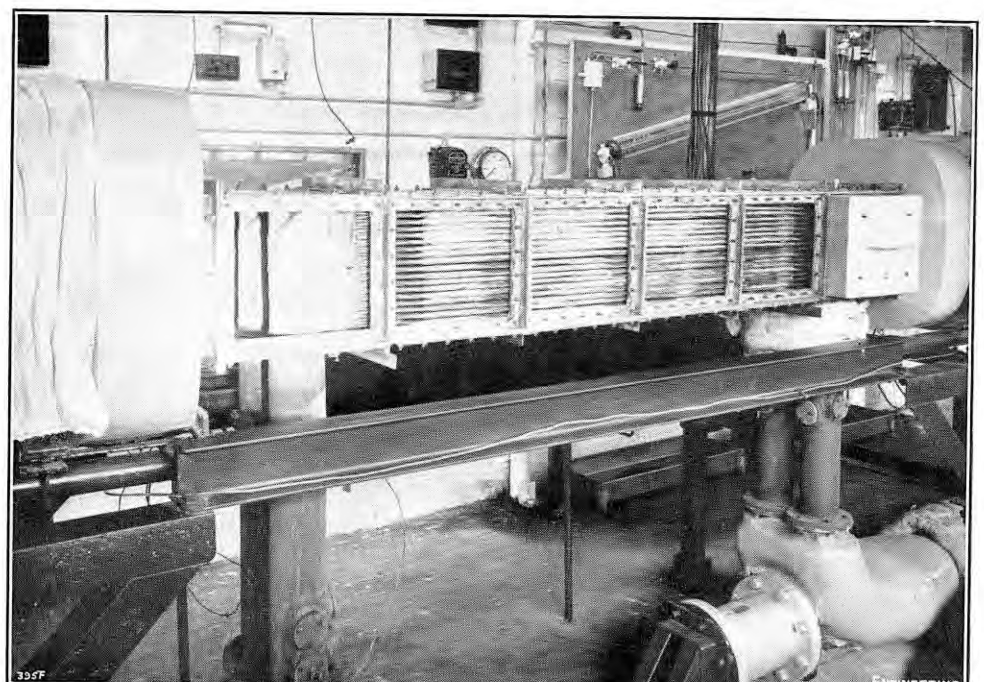


FIG. 12. HEAT EXCHANGER WITH SIDE COVERS REMOVED.

FIG. 13. HEADERS AT GAS-INLET END.

RECUPERATIVE HEAT EXCHANGER FOR GAS TURBINES.

HEAT EXCHANGERS, LIMITED, LONDON.

(*For Description, see Page* 449.)

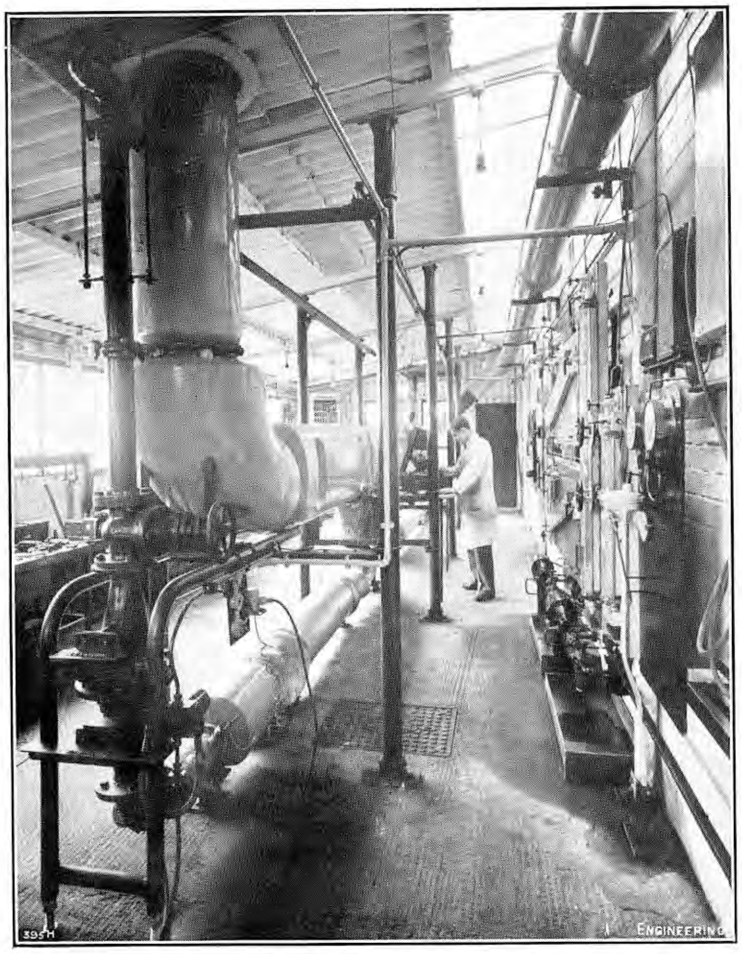


FIG. 14

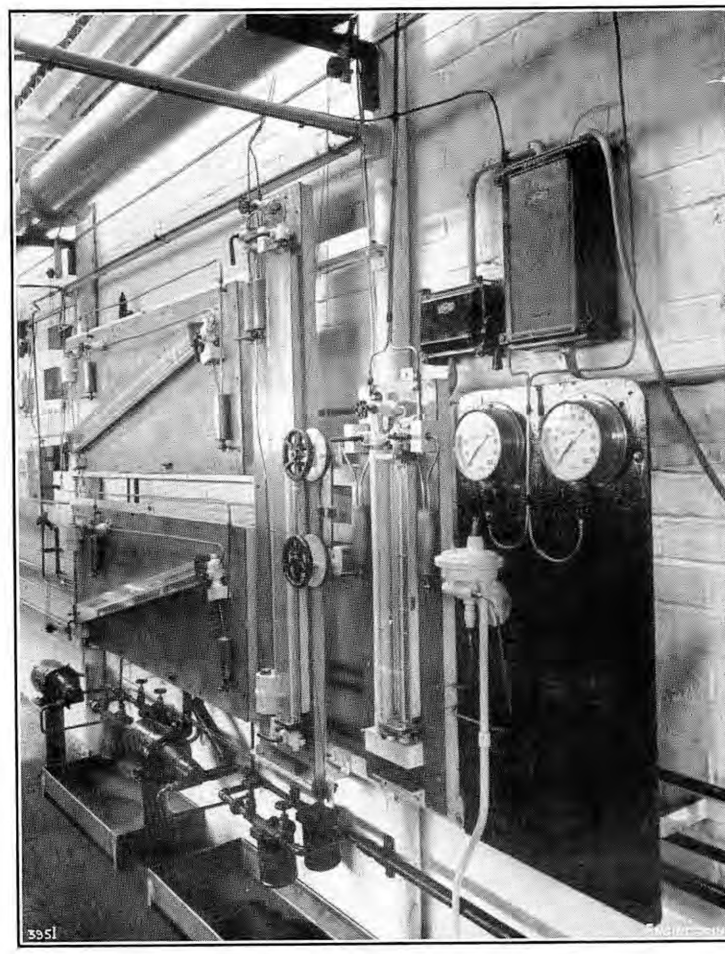


FIG. 15.

FIGS. 14 AND 15. FULL-SCALE PLANT FOR PERFORMANCE TESTS.

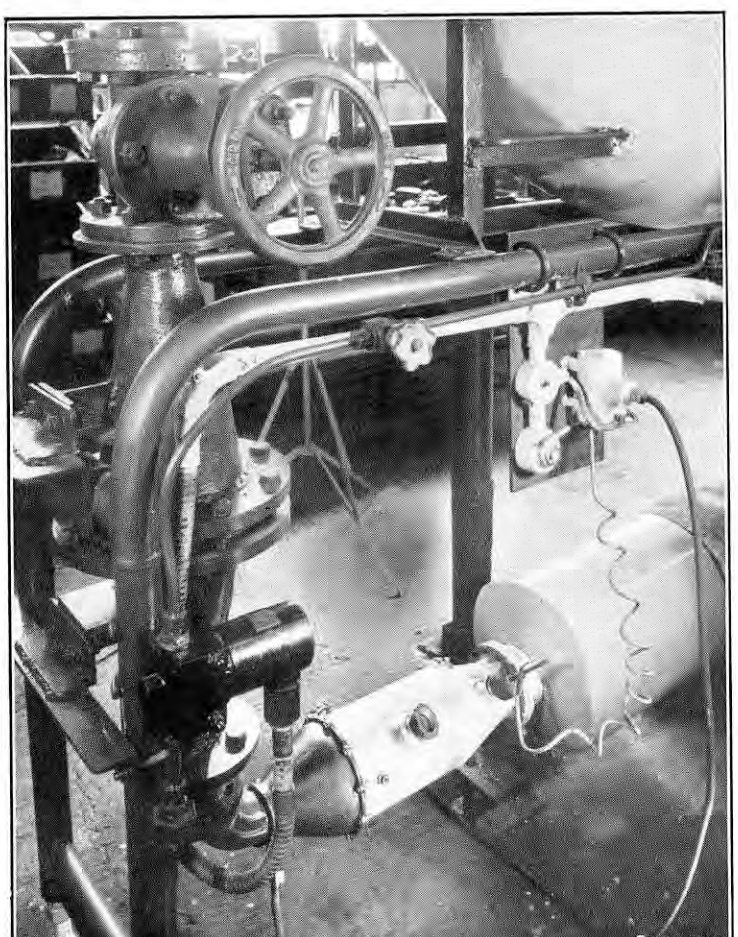


FIG. 16. HIGH-PRESSURE COMBUSTION CHAMBER.

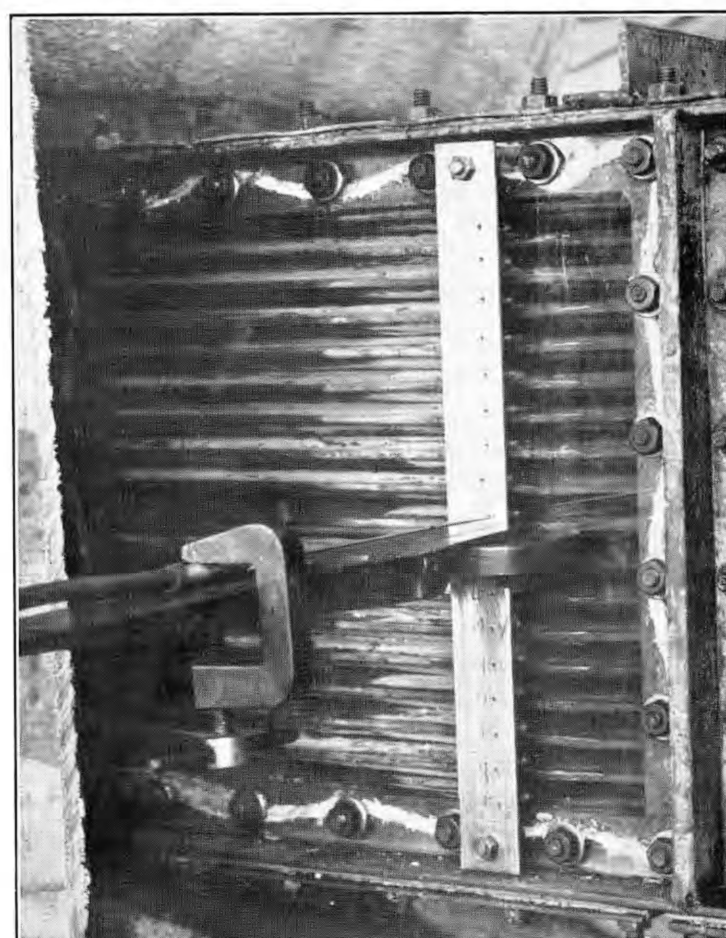


FIG. 17. PITOT TUBE FOR MEASURING EXTERNAL DISTRIBUTION.

at a temperature of between 300 deg. F. and 500 deg. F. and a pressure of approximately four atmospheres, and the other at a temperature between 750 deg. F. and 1,000 deg. F. with a pressure slightly above that of the atmosphere. On the high-pressure side, the compressed air is raised to the requisite temperature by means of a standard Rolls-Royce Dart combustion chamber arranged to burn aviation kerosene so as to give clean combustion; this is illustrated in Fig. 16, on Plate XXXVI. On the low-pressure side, the air is heated by a special combustion chamber designed by the Shell Petroleum Company, Limited, and constructed by Heat Exchangers, Limited; a photograph of this unit is reproduced in Fig. 9, opposite. The specification to which it was designed called for a range of gas temperatures of from 400 to 1,000 deg. F. and a rate of flow ranging from 0·25 lb. per second to 2 lb. per second with a pressure drop not exceeding 6 in. of water for any combination of these conditions; subsequent tests showed that these requirements were completely satisfied. The chamber is lined with Sillimanite; this was ready mixed, rammed in position and, after pre-drying in an oven, was fired *in situ*. The chamber is provided with a variable swirler, and other means for adjusting and controlling the air quantities and distribution, while sight holes of the usual form are fitted, with additional windows at the discharge end for observing the condition of the lining both on load and immediately after the load is removed. Both distillate and residual fuels can be burnt and although the former has been used in the tests carried out so far, the necessary equipment is being installed for burning residual fuels and it is hoped that tests with such fuels will be started in the near future. As a safety precaution, both combustion chambers are fitted with electronic flame-failure devices, arranged to operate magnetic shut-down valves installed in the various fuel lines.

The methods employed for measuring the different variables follow accepted practice and, in general, standard instruments are used. Air and gas flows, for example, are measured with British Standard sharp-edged orifices and the usual corrections made for humidity, temperature, etc. Pressure differences across these orifices and across the two sides of the heat exchanger are measured with single-leg vertical or inclined-tube manometers; some of the latter type of manometers can be seen in Fig. 15, on Plate XXXVI.

Gas and air temperatures are measured with chromium-alumel thermocouples connected through a multi-point switch to a potentiometer; and duct wall temperatures are measured as a check on thermocouple radiation losses. Traverse measurements of temperature and total head have been made at all measuring sections to ensure representative readings; typical performance figures are set out in Table I below from which it will be seen that the heat exchanger more than fulfils design considerations.

TABLE I.—*Performance Test Data.*

Mass flow, high-pressure side	4,500 lb. per hour.
Inlet temperature, high-pressure side ..	390 deg. F.
Outlet temperature, high-pressure side ..	659 deg. F.
Mean pressure, high-pressure side	59·6 lb. per sq. in. abs.
Mass flow, low-pressure side	4,500 lb. per hour.
Inlet temperature, low-pressure side ..	870 deg. F.
Mean pressure, low-pressure side	14·65 lb. per sq. in. abs.
Heat recovery	56 per cent.
Sum of percentage pressure drops on high- and low-pressure sides	$1\frac{3}{8}$ per cent.

Results so far obtained are distinctly encouraging and show that the unit is capable of satisfactory operation with gas turbines. The unique form of construction used, which is covered by patents, confers several advantages, the most outstanding of which is, probably, the small passage diameter that can be obtained at moderate cost. The end connections also form an important part of the design, as their shape enables complete counter-flow to be obtained and at the same time permits a number of elements to be built up into a complete unit with the minimum of trouble. Furthermore, problems regarding expansion are considerably simplified and the facilities for cleaning, both internally and externally, are comparable with most existing designs.

LITERATURE.

The Design of Prismatic Structures.

By A. J. ASHDOWN, A.M.I.Struct.E. Concrete Publications, Limited, 14, Dartmouth-street, London, S.W.1. [Price 8s.]

THIS is one of the Concrete Series of monographs, written primarily for the practising designer and draughtsman. The short title refers primarily to "planar reinforced concrete slabs which meet at an angle at their longitudinal junctions" in such a way that the slabs are loaded transversely, as in pitched roofs and the bottoms of bunkers. The calculations are based on the usual simplifying assumptions, so that the publishers' claim that the formulæ and calculations are much simpler than for "shell" roofs is really begging the question, since an attempted solution by the methods of the theory of elasticity would almost certainly be more arduous and intractable than that of a shell of circular or parabolic section. The typical set of equations solved by a relaxation method is of the most primitive order and the claim that "the relaxation method described in the text is similar to that of Professor R. V. Southwell" might almost be interpreted as an admission by the author that he is not very familiar with the contents of Professor Southwell's two well-known Clarendon texts.

These criticisms on the theoretical side of the work, however, do not detract from its practical value as a designer's handbook, because no one familiar with the necessities, the urgencies and the limitations of drawing office methods would imagine that design can be made to depend on the everyday solutions of either eighth-order differential equations or of the types of problem which Professor Southwell and his many gifted pupils have used during the past 15 years to test the expanding range and power of relaxation methods. The four principal chapters—prismatic structures of one span, multiple-bay structures, continuous prismatic structures, and prismatic structures with sloping ends—cover a considerable variety of useful design problems and the methods are well explained and clearly set out.

Complêments d'Hydraulique, Part II.

By PROFESSOR L. ESCANDE. Dunod, 92, Rue Bonaparte, Paris, 6me. [Price 1,900 fr.]

THE extensive indoor and outdoor hydraulic laboratories associated with l'Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique de Toulouse and typical examples of the valuable scale model work executed there, under the direction of Professor L. Escande, are well known. The work of this institution in the field of hydraulics was started by Professor C. Camichel, and now provides Professor Escande with abundant scope for frequent and able contributions to French scientific societies and the technical Press. A selection of his papers was published in 1947 under the title *Complêments d'Hydraulique*, Part I, now supplemented by Part II. Among other questions, Part I introduced the powerful and elegant graphical Schnyder-Bergeron approach to water-hammer accompanying the closure of a butterfly valve following a rupture of a control device, surges in tailrace tunnels under pressure, and surge distribution along a non-uniform pipeline. Although the mathematical treatment may appear to be somewhat academic, such problems are of practical importance, and the application of the Schnyder-Bergeron method to transient hydraulic phenomena in turbine and pumping plants is not too difficult for use by hydraulic engineers. It is of special value to those who have a preference for graphical solutions to hydraulic problems, and has been extended to electrical work in Bergeron's *Du Coup de Bélier en Hydraulique Au Coup de Foudre en Electricite*, issued by the same publishers as the present work.

Four of the eight chapters in Part II of *Complêments d'Hydraulique* extend the development of this method to penstock water-hammer questions relating to recent power stations in France, notably Génessiat, Olette and Brevières. The conditions which have been studied are the simultaneous operation of an intake gate and turbine inlet valve or guide apparatus, including aeration of effects; the closure of a servomotor-operated butterfly valve at the downstream end of a pipeline against free discharge to atmosphere—this introduces the valve characteristics and closure law; and the operation of a turbine pressure-relief valve. The general conclusions which have been reached are both interesting and reassuring to those who have had previous doubts on the conditions which may arise in the hydraulic system in these circumstances.

Professor Escande is a recognised authority on surge chambers and his *Recherches Théoriques et Experimentales sur les Oscillations de l'Eau dans les Chambres d'Equilibre* is well known to those dealing with hydro-electric plant regulation. Two chapters of the present publication provide further material in connection with the effect of the connection between the tunnel penstock system and the surge chamber, including throttling, using the Schnyder-Bergeron method; and surge chambers in series, including the case where discharges are received from side-streams or neighbouring catchments. For this study, the author has extended the classic work of Calame and Gaden on *Théorie des Chambres d'Equilibre* and his own more recent work, based on finite differences, as treated in *Méthodes Nouvelles Pour Le Calcul des Chambres d'Equilibre*, published by Dunod in 1949.

The effective utilisation of model tests to disclose important conditions which prove intractable to mathematical analysis is illustrated by two chapters, the first of which deals with the determination of the free surface, discharge and pressure distribution on a combination of sector gate and Creager-type overflow crest; this has been supplemented by an interesting comparison with the calculated results, based on the Prasil graphical method for construction of streamlines. The other chapter deals with the conditions which may accompany simultaneous operation of crest gates and deep sluices in a dam; this emphasises the importance of aeration and the possibility of dangerous structural conditions arising in certain circumstances. Part II of the *Complêments d'Hydraulique*, and the other works of Professor Escande, are of particular value to the specialist in hydraulic engineering, and we look forward to a further report of his interesting research work in Part III.

Advanced Strength of Materials.

By D. A. R. CLARK, M.Sc. Tech., M.I.Mech.E., A.F.R.Ae.S. Blackie and Son, Limited, 16-18, William IV-street, London, W.C.2. [Price 35s. net.]

THE justification of a new text-book for use in courses of study on the strength of materials is to be found in the presentation rather than in the matter presented. In this book, Mr. Clark largely meets the needs of those studying the subject for the final engineering degree examination of London University, and for the examination for associate membership of the senior professional institutions.

Following a discussion of direct stress and strain, the author proceeds, in the next four chapters, to the theory of beams with ends simply supported or built in, continuous beams, and the problem of stress under prescribed conditions of loading. The subject-matter of Chapter VI furnishes alternative means of dealing with beams, by the method of strain energy, the principle of which can be applied also to the next of the principal topics, namely, torsion in shafts, including the case of helical springs. In easy stages the reader's attention is thus drawn to the computation of compound stresses. Extensions of the foregoing theory are given in Chapters IX to XII, in the analytical consideration of thick cylinders subjected to fluid pressure, struts, stresses in curved bars (of which a crane hook is an important example) and the stresses produced in rotating discs and structural components of cylindrical shape. Due attention is paid to the theory of flat plates, and the computational side of the subject is explained by a wide variety of illustrative examples and exercises, with answers. The need for conciseness in a book of this kind is obvious, but the author's endeavours in this direction would seem to have exceeded the bounds of discretion in certain places—as in the final chapter, on the vibration of shafts, where the phenomenon of whirling is introduced by the statement: "It will be impossible to have a shaft in which the centre of gravity coincides with the axis of rotation. . . ."

THE SAMPLING OF SMALL COAL.

Fig. 1. ASH CONTENT IN ELEMENTS.

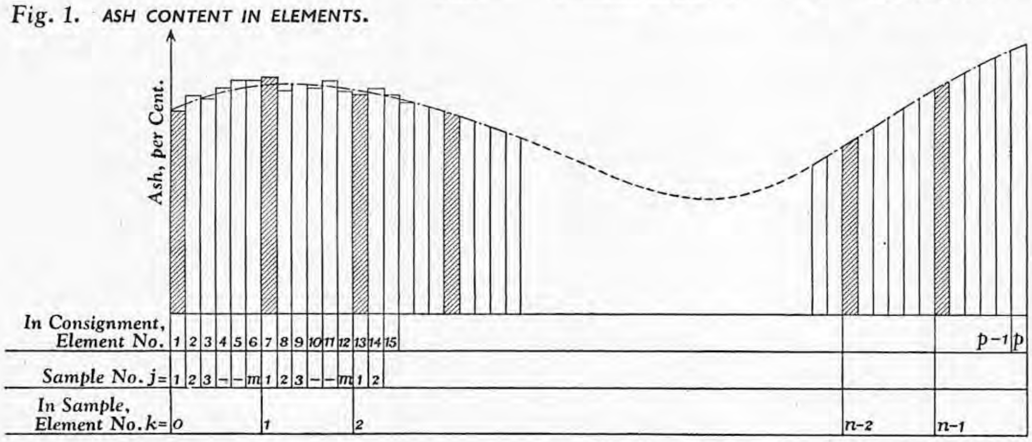


Fig. 2. ASH CONTENT IN SUB-ELEMENTS OF AN INCREMENT.

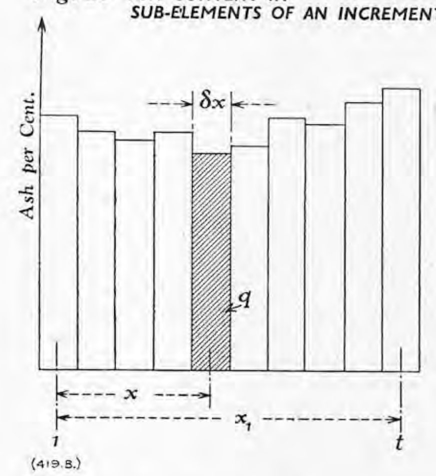
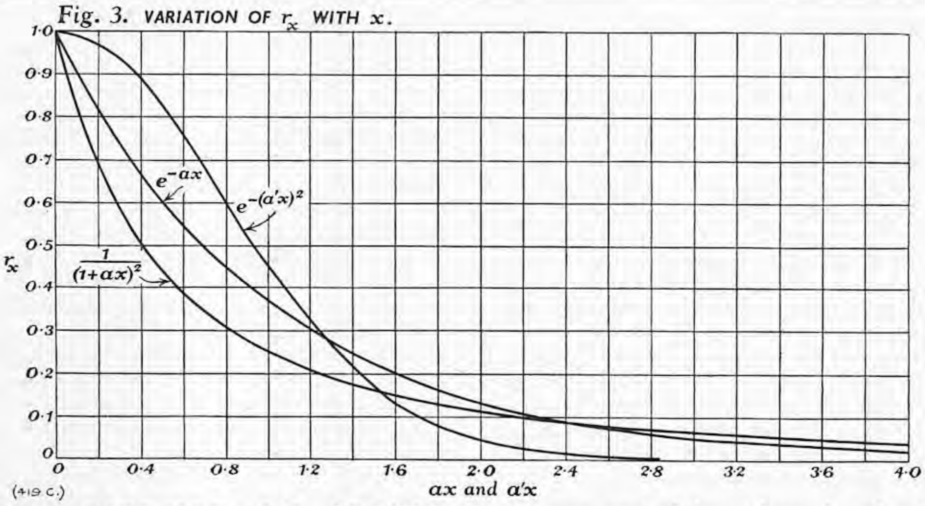


Fig. 3. VARIATION OF r_x WITH x.



THE SAMPLING OF SMALL COAL.

By E. T. G. EMERY.

THE sampling of small coal for analysis is usually carried out by taking evenly-spaced increments from the consignment of coal while it is in motion. In order to economise in the amount of coal sampled, it is necessary to know the minimum number of increments which will yield an analytical result of a given precision. It has been found that, for a given size of increment, the principal factors affecting the number of increments are the mean ash content and the maximum size of the coal, but size distribution and the variation of ash content with size may affect the results to a greater or lesser extent. It is generally conceded that, if the sampling is designed to limit the variability of the ash determination to some pre-determined value, other properties of the coal, such as the content of volatile matter, calorific value, etc., will be obtained with sufficient precision.

Most of the experimenting which has been carried out in the past has been with homogeneous coal; that is to say, coal from a single source which has been fairly thoroughly mixed before sampling. In practice, however, coal is not delivered in this condition. A shipload is often comprised of coals from a number of different pits; a trainload from a single colliery may include wagons filled from different seams, or from different parts of the same seam; and even a single wagon may be affected by segregation. Thus the general level of ash content may vary from place to place in the consignment of coal, and a sampling procedure for commercial application should take this factor into account.

The following notes dealing with the theory of coal sampling as normally carried out are expressed in terms of the functions ordinarily used in statistical work. It may be useful to commence by summarising the definitions of these functions. Given n values of a variable x, the mean,

$$\bar{x} = \frac{\sum x}{n}, \quad . \quad . \quad . \quad (1)$$

and the variance,

$$S^2 = \frac{\sum (x - \bar{x})^2}{n}. \quad . \quad . \quad . \quad (2)$$

S, the square root of the variance, is referred to as the "standard deviation." Given n pairs of values, x_1, x_2, the co-variance is defined as

$$\text{cov}\,(x_1, x_2) = \frac{\sum (x_1 - \bar{x}_1)(x_2 - \bar{x}_2)}{n}. \quad . \quad . \quad (3)$$

The coefficient of correlation is then

$$r = \frac{\text{cov}\,(x_1, x_2)}{S_1\, S_2}, \quad . \quad . \quad . \quad (4)$$

where S_1 and S_2 are the standard deviations of the two variables, considered separately.

A particular case occurs when x_1 and x_2 are drawn from the same "population" with variance S^2. The coefficient of correlation is then referred to as the coefficient of intraclass correlation, and it is given by the formula

$$r = \frac{\text{cov}\,(x_1, x_2)}{S^2}. \quad . \quad . \quad . \quad (5)$$

The quantity of coal to be sampled will be referred to as the "consignment," and it will be assumed that the consignment is spread out along a trough of constant cross-sectional area A, the area being not many times the cross-sectional area of the largest piece of coal. The consignment is assumed to be divided into p "elements," an element selected for testing being referred to as an "increment."

Referring to Fig. 1, in which the elements comprising the first sample are shown hatched, let

n = the number of increments in one sample;
m = distance measured in number of elements from the middle of one increment to the middle of the next in a given sample;
= the number of samples of n increments in the consignment of p elements;
p = $m\,n$;
y = the ash content of a single increment;
Y_j = the average ash in the jth sample of n increments;
Y = the average ash in the whole consignment;
a = y − Y = the error of a single increment;
e_j = Y_j − Y = the error of a sample; and
σ^2 = the variance of samples.

$$e_j = Y_j - Y = \frac{1}{n}\sum_{k=0}^{n-1} y_{j+km} - Y$$
$$= \frac{1}{n}\sum_{k=0}^{n-1} (a_{j+km} + Y) - Y = \frac{1}{n}\sum_{k=0}^{n-1} a_{j+km}$$

$$\sigma^2 = \frac{1}{m}\sum_{j=1}^{m} e_j^2 = \frac{1}{m}\sum_{j=1}^{m}\left\{\frac{1}{n}\sum_{k=0}^{n-1} a_{j+km}\right\}^2$$
$$= \frac{1}{m\,n^2}\sum_{j=1}^{m}\left\{\sum_{k=0}^{n-1} a^2_{j+km} + 2\sum_{k=0}^{n-2}\sum_{h=k+1}^{n-1} a_{j+km}\, a_{j+hm}\right\}$$

Let

$$S^2 = \frac{1}{m\,n}\sum_{j=1}^{m}\sum_{k=0}^{n-1} a^2_{j+km}$$

= variance of errors in individual increments,

$$C_{qm} = \sum_{j=1}^{m}\sum_{k=0}^{n-1-q} \frac{a_{j+km}\, a_{j+(k+q)m}}{m\,(n-q)}$$

and

$$r_{qm} = \frac{C_{qm}}{S^2}$$

= intraclass correlation between increments spaced distance $q\,m$ elements apart;

then

$$\sigma^2 = \frac{1}{m\,n^2}\left\{m\,n\,S^2 + 2\sum_{q=1}^{n-1} m\,(n-q)\,C_{qm}\right\}$$
$$= \frac{S^2}{n}\left\{1 + 2\sum_{q=1}^{n-1}\frac{n-q}{n}\, r_{qm}\right\} \quad . \quad . \quad . \quad (6)$$

This equation gives the variance σ^2 of a sample of n increments in terms of the variance S^2 of a single increment, and of the various coefficients of correlation between the increments. It will be seen from this that the usual equation $\sigma^2 = \frac{S^2}{n}$ is true only when all values of r are zero; that is to say, when there is no systematic variation in the general level of ash content from place to place in the consignment of coal.

In practice, it will probably be found that r_{qm} will diminish as $q\,m$ increases (i.e., as the increments are spaced farther apart). To obtain a rough idea of the implications of equation (6), suppose that r_{qm} varies in such a way that

$$r_{qm} = r^q_m. \quad . \quad . \quad . \quad (7)$$

It can be shown that the equation becomes

$$\sigma^2 = \frac{S^2}{n}\left\{1 + \frac{2\,r_m}{1 - r_m} - \frac{2\,r_m\,(1 - r^n_m)}{n\,(1 - r_m)^2}\right\}. \quad (8)$$

Suppose $n = 50$ and $r_m = 0 \cdot 1$, then

$$\sigma^2 = \frac{S^2}{n}\left\{1 \cdot 22\right\}.$$

Thus, with the law of variation assumed by equation (7), the error in the conventional formula is 22 per cent. when r_m has the value $0 \cdot 1$.

The experimental investigation of equation (6) is probably the most urgent need. Direct measurements of correlation coefficients for various spacings of increments could be carried out on different types of consignment, using any convenient fixed sizes of increments (such as those recommended in British Standard specifications) without waiting for experimental investigation of the theory given below for

THE SAMPLING OF SMALL COAL.

Fig. 4. THE VARIANCE RATIO $\frac{S^2}{u^2}$ CURVES CORRESPONDING TO FIG. 3.

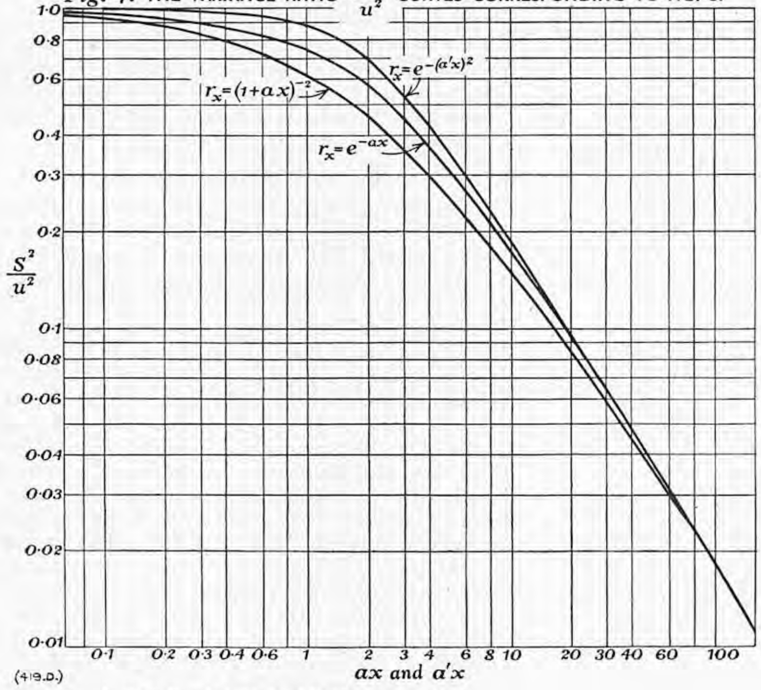


Fig. 5. THE VARIANCE RATIO $\frac{S_1^2}{S_p^2}$ FOR VARIOUS VALUES OF ax.

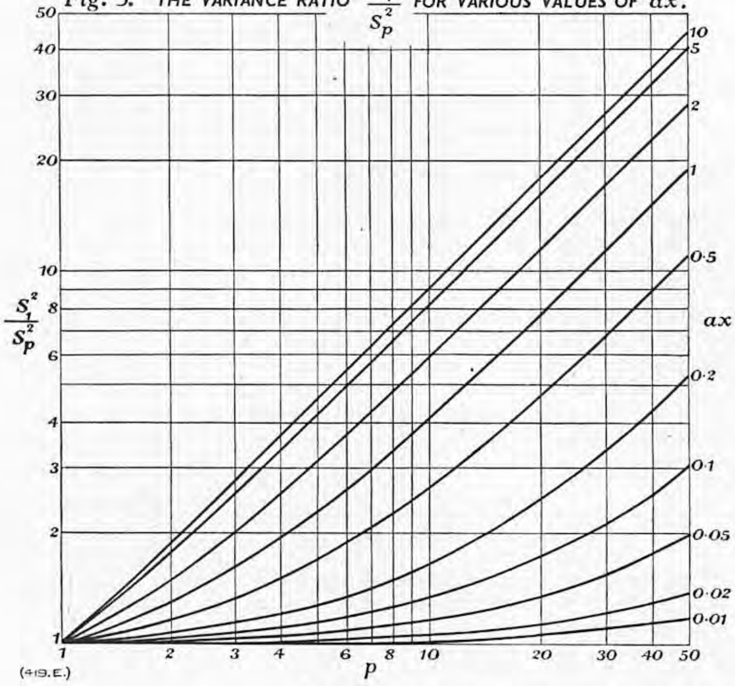


Fig. 6. ASH CONTENT IN ELEMENTS.

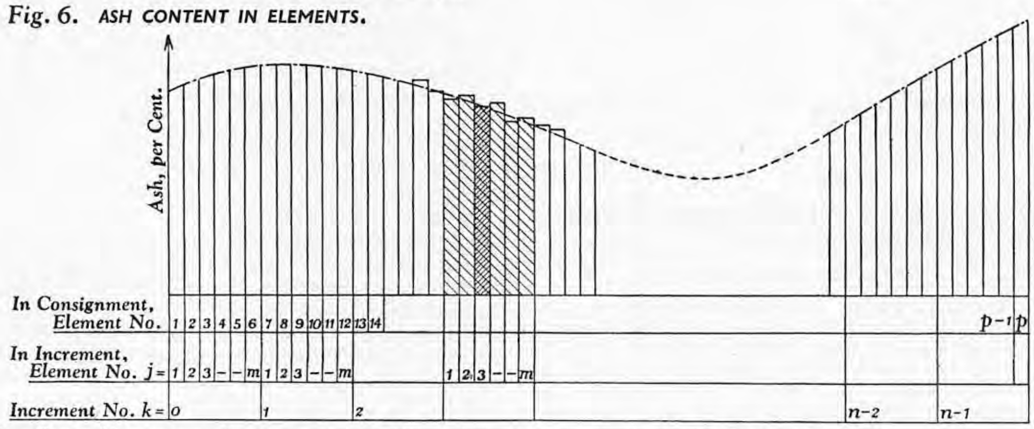
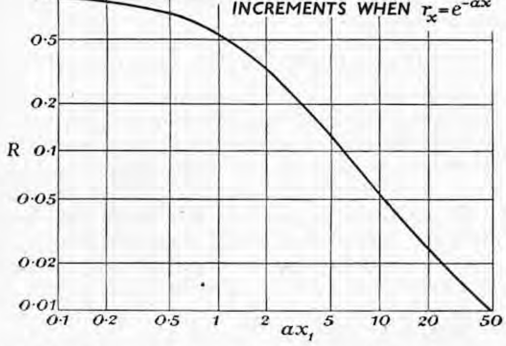


Fig. 7. CORRELATION BETWEEN CONSECUTIVE INCREMENTS WHEN $r_x=e^{-ax}$



the effect of increment size upon the precision of the analytical results.

The effect of change in the size of the increment can be determined quite simply by means of equation (6). Regarding each increment as a consignment, let it be divided into t sub-increments or elements. The "sample" consists of all t elements and so $m = 1$. If the dimensions of the increment considered in the development of equation (6) were only big enough to ensure that representative proportions of the various-sized pieces were included, practical difficulty would be met in sub-dividing the increment into t elements. This difficulty is surmounted by imagining the existence of some kind of X-ray apparatus which will reveal the ash content of the coal contained between two vertical planes set at any distance apart along the length of the trough without disturbing the coal. The planes will pass through pieces of coal and the element will include only those parts of the pieces which are contained between the planes. If S^2 is the variance of an increment and u^2 is the variance of an element consisting of $\frac{1}{t}$ th part of an increment, it is found from equation (6) that

$$S^2 = \frac{u^2}{t}\left\{1 + 2\sum_{q=1}^{t-1}\frac{t-q}{t} r_q\right\}. \quad (9)$$

Referring to Fig. 2, opposite, let

x_1 = distance between first and last elements;
x = distance between first and qth elements; and
δx = width of an element.

Then

$$q = \frac{x}{\delta x}, \quad t = \frac{x_1}{\delta x}, \quad r_q = r_x.$$

Substituting in equation (9),

$$S^2 = \frac{u^2}{x_1}\left\{\delta x + 2\sum_{x=0}^{x_1}\frac{x_1 - x}{x_1} r_x\,\delta x\right\}$$

In the limit, as δx tends to zero,

$$S^2 = \frac{2u^2}{x_1^2}\int_0^{x_1}(x_1 - x)\,r_x\,dx. \quad (10)$$

This provides a fundamental equation for finding the variance of a single increment. To evaluate it, it is necessary to know the value of the characteristic constant u^2 and the law of variation of r_x with x. Both will depend upon the general properties of the coal being sampled, such as the maximum size, the size distribution, the mean ash content, the density distribution, etc. Since we have considered a trough of coal of constant cross section, x_1 represents volume to a suitable scale.

Unfortunately, there is no direct method of finding u^2 and r_x; the best that can be done is to vary the size of the increment and to note whether the variations in S^2 are in agreement with some predetermined law of variation of r_x. There exists the practical difference between taking an actual increment for analysis and the theoretical measurement of ash content *in situ*, as assumed in the development of the theory. When the increment is reasonably large, it can be expected that the difference between the two methods will have little effect; but, as the size of increment is reduced, the chance inclusion or non-inclusion of whole pieces of coal in the practical increments will cause additional variation to that expressed by equation (10). It must be recognised, therefore, that there is a practical restriction on the smallness of the increment which can be used in the experiments.

The limiting size may, however, be much smaller than has hitherto been considered possible. It has been known for some time that values of S^2 plotted against size of increment on a logarithmic scale yield a straight line when the increments are all above a certain size, but that the line curves sharply when the increments are small. It has been assumed that this departure from linearity is due to unrepresentative increments being obtained when the size is reduced, but it is shown below that the curvature is in accordance with theory.

The coefficient of correlation r_x, must have the value unity when $x = 0$; it will probably reduce in value as x increases, and, for all practical purposes, will become zero at some sufficiently large value of x. It will always remain positive. Many functions having these properties could be written down, but attention will be confined here to three of the simplest, given below as equations (11), (12) and (13), in each of which a scale factor a has been introduced so as to allow the curve to be spread as far along the x axis as may be desired. The curves are illustrated in Fig. 3, opposite.

$$r_x = e^{-ax} \quad (11)$$
$$r_x = e^{-(ax)^2}. \quad (12)$$
$$r_x = (1 + ax)^{-2}. \quad (13)$$

Substituting each of these in turn in equation (10), the following results are obtained:

From equation (11),

$$S^2 = \frac{2u^2}{a^2x_1^2}\left\{a x_1 - 1 + e^{-ax_1}\right\}. \quad (14)$$

From equation (12),

$$S^2 = \frac{u^2}{a^2x_1^2}\left\{a x_1\sqrt{\pi}\,\alpha_h - 1 + \sqrt{2\pi}\,Z_h\right\}, \quad (15)$$

where Z_h and α_h are, respectively, the ordinate and the area corresponding to the argument $h = \sqrt{2}\,a\,x$ of the well-known "probability curve":—

$$Z_h = \frac{e^{-\frac{h^2}{2}}}{\sqrt{2\pi}} \quad (16)$$

$$\alpha_h = \int_{-h}^{h} Z_h\,dh. \quad (17)$$

Alternatively, writing

$$a' = \frac{2\,a}{\sqrt{\pi}}, \quad h = \sqrt{\frac{\pi}{2}}\,a'\,x,$$

$$S^2 = \frac{2\,u^2}{a'^2\,x_1^2}\left\{a'\,x_1\,\alpha_h - \frac{2}{\pi} + \frac{2\,\sqrt{2}\,Z_h}{\sqrt{\pi}}\right\}. \quad (18)$$

From equation (13),

$$S^2 = \frac{2\,u^2}{a^2\,x_1^2}\left\{a\,x_1 - \log_e(1 + a\,x_1)\right\}. \quad . \quad (19)$$

The values of $\frac{S^2}{u^2}$ given by these equations are plotted against $a\,x$ on Fig. 4, page 453, to a logarithmic scale. It will be seen that the curves are practically coincident for values of $a\,x$ in excess of about 100.

Experiments could be devised for testing whether any given law (such as that of equation (11), for example) can be taken as being representative of the variation of r_x in an actual consignment. At the same time, the experiments would establish the factor relating $a\,x$ to the weight or volume of increment.

Let

v = the volume of the smallest increment for which it can be reasonably assumed that the law will be followed ;
S_1^2 = variance of a single increment of size v ; and
S_p^2 = variance of a single increment of size $p\,v$.

A curve of the type shown in Fig. 4 could be used for the construction of a family of curves relating $\frac{S_1^2}{S_p^2}$ to p for various values of $a\,x$. An example is shown in Fig. 5, page 453, which has been drawn to correspond to equation (11). Experimental values of $\frac{S_1^2}{S_p^2}$ plotted on this graph would show whether the law was suitable and would indicate the value of $a\,x$ corresponding to v; but, owing to the scattering of the points which occurs as the result of experiments, it might be difficult to decide which of various possible laws is the most suitable.

The coefficient of correlation between consecutive increments of a given size is easily measured, and since this is dependent upon r_x, it could be used to provide a further test of the validity of a hypothesis concerning the law of r_x.

Making a slight change in the notation previously used, suppose a consignment of p elements to be divided into n increments, each consisting of m elements (see Fig. 6, page 453).

Let

y = the ash content of a single element ;
Y_k = the average ash in the kth increment (consisting of m elements) ;
Y = the average ash in the whole consignment ;
a = $y - Y$ = the error of a single element ; and
e_k = $Y_k - Y$ = the error of an increment.

$$e_k = Y_k - Y = \frac{1}{m}\sum_{j=1}^{m} y_{km+j} - Y$$

$$= \frac{1}{m}\sum_{j=1}^{m}(a_{km+j} + Y) - Y$$

$$= \frac{1}{m}\sum_{j=1}^{m} a_{km+j}$$

$$e_{k+1} = \frac{1}{m}\sum_{j=1}^{m} a_{(k+1)\,m+j}$$

$$\text{cov}\,(Y_k, Y_{k+1}) = \frac{1}{n-1}\sum_{k=0}^{n-2} e_k \,.\, e_{k+1}$$

$$= \frac{1}{n-1}\,\frac{1}{m^2} \times$$

$$\sum_{k=0}^{n-2}\left\{\sum_{j=1}^{m} a_{km+j}\sum_{j=1}^{m} a_{(k+1)\,m+j}\right\}$$

Writing

$$\gamma_q = a_x\,a_{x+q}, \text{ where } x \text{ has any value}$$

and

$$C_q = \frac{1}{n-1}\sum_{k=0}^{n-2}\gamma_q$$

= co-variance of elements distance q apart,

it can be shown that the above expression becomes

$$\text{cov}\,(Y_k, Y_{k+1}) = \frac{1}{m^2}\left\{\sum_{q=1}^{2m} q\,C_q - 2\sum_{q=m+1}^{2m}(q - m)\,C_q\right\}.$$

In the present notation, equation (9) becomes

$$S^2 = \frac{u^2}{m}\left\{1 + 2\sum_{q=1}^{m-1}\frac{m-q}{m}\,r_q\right\}.$$

The coefficient of correlation between Y_k and Y_{k+1} is

$$R = \frac{\text{cov}\,(Y_k, Y_{k+1})}{S^2}$$

$$= \frac{\frac{1}{m^2}\left\{\sum_{q=1}^{2m} q\,C_q - 2\sum_{q=m+1}^{2m}(q-m)\,C_q\right\}}{\frac{u^2}{m}\left\{1 + 2\sum_{q=1}^{m-1}\frac{m-q}{m}\,r_q\right\}}.$$

But $\frac{C_q}{u^2} = r_q$ and therefore

$$R = \frac{\sum_{q=1}^{2m}\frac{q}{m}\,r_q - 2\sum_{q=m+1}^{2m}\frac{q-m}{m}\,r_q}{1 + 2\sum_{q=1}^{m-1}\frac{m-q}{m}\,r_q}.$$

If we put $q = \frac{x}{\delta x}$, $m = \frac{x_1}{\delta x}$, $r_q = r_x$, then, in the limit, where $\delta\,x$ tends to zero,

$$R = \frac{\int_0^{2x_1} x\,r_x\,dx - 2\int_{x_1}^{2x_1}(x - x_1)\,r_x\,dx}{2\int_0^{x_1}(x_1 - x)\,r_x\,dx} \quad . \quad . \quad (20)$$

$$= \frac{\int_0^{x_1} x\,r_x\,dx - \int_{x_1}^{2x_1} x\,r_x\,dx + 2x_1\int_{x_1}^{2x_1} r_x\,dx}{2\,x_1\int_0^{x_1} r_x\,dx - 2\int_0^{x_1} x\,r_x\,dx}. \quad (21)$$

For the law of equation (11)—($r = e^{-ax}$)—equation (21) gives

$$R = \frac{(e^{-ax_1} - 1)^2}{2\,(e^{-ax_1} + a\,x_1 - 1)} \quad . \quad : \quad (22)$$

Values of R calculated from equation (22) are plotted against $a\,x$ in Fig. 7, on page 453.

ROYAL INSTITUTION.—We have received a copy of the Royal Institution's programme of Friday evening discourses and afternoon lectures which are to be held before Christmas at the Royal Institution, 21, Albemarle-street, London, W.1. Among the evening discourses, which begin at 9 p.m., may be mentioned "Experiments with High Energy Nucleons and Quanta," by Sir John Cockcroft, C.B.E., F.R.S., on November 2; "New Materials in Engineering," by Dr. T. E. Allibone, F.R.S., M.R.I., on November 16; "Radio-Astronomy," by Mr. J. A. Ratcliffe, O.B.E., F.R.S., on November 23; and "The Mechanics of Metal Crystals," by Professor E. N. da C. Andrade, F.R.S., M.R.I., on December 14. Professor Andrade is also giving a course of afternoon lectures on "The Physics of the Deformation of Metals," at 5.15 p.m. on Thursdays, November 1, 8, 15 and 22; and a course of three afternoon lectures on "Distance Measurements in Astronomy" is to be presented by Professor Sir Harold Spencer Jones, F.R.S., M.R.I., at 5.15 p.m. on Thursdays November 29, December 6 and 13. Non-members of the Institution may attend afternoon lectures by paying a subscription of 6s. for a course of three lectures and 8s. for a course of four lectures.

SHEET AND STRIP METAL USERS' TECHNICAL ASSOCIATION.—The annual winter conference of the Sheet and Strip Metal Users' Technical Association will be held, this year, on October 31 and November 1 and 2, at the Charing Cross Hotel, Strand, London, W.C.2. On the first day, visits will be paid to the works of Vauxhall Motors, Ltd., Luton, and Briggs Motor Bodies, Ltd., Dagenham, and to the industrial application showroom of Philips Electrical, Ltd. On Thursday, November 1, at 10.30 a.m., the Association's annual general meeting will be held, and, at 11.30 a.m., the 4th Sheet-Metal-Working Exhibition will be officially opened. At 2.15 p.m., a paper by Mr. H. E. Dixon and Dr. H. G. Taylor, on "Resistance Welding: Research Progress by the British Welding Research Association," will be presented. At 7.0 for 7.30 p.m., an informal dinner will be held at Simpson's Restaurant, Strand. On the morning of Friday, November 2, a discussion on "Tooling for Small-Quantity Production" will be introduced by Mr. T. Elkington, Mr. W. Dunn, Mr. H. C. Gregory and others. In the afternoon, at 2.15 p.m., a discussion on "Materials Handling for Presswork and Assembly Lines" will be introduced by Mr. H. B. Mott, Mr. O. J. B. Orwin, Mr. K. B. Warwick and others. Further particulars may be obtained from the honorary secretary, Mr. Alastair McLeod, 49, Wellington-street, Strand, London, W.C.2.

THE INSTITUTE OF METALS.

(*Concluded from page 423.*)

WHEN the members reassembled in the Ca'Foscari, Venice, on the morning of Tuesday, September 18, for the last technical session of the Institute of Metals Autumn meeting in Italy, Professor A. J. Murphy occupied the chair.

FRICTION IN WIREDRAWING.

The first paper considered was entitled "Friction in Wire Drawing" and was by Mr. H. G. Baron and Professor F. C. Thompson. It was presented by Professor Thompson. The paper described work carried out in the Department of Metallurgy of the University of Manchester, and was divided into two main sections. The authors stated that the first section contained the results of a short investigation of the magnitude of the frictional loss in drawing 65 : 35 brass wire, using carbide dies with and without parallel extensions. These results confirmed the view that the process was the more efficient as the reduction of area became larger. The second main section of the paper dealt with the coefficient of friction between the wire and the die, calculated on the basis of wiredrawing theory. Many theories could be used, but, fortunately, G. D. S. MacLellan, in a paper before the Iron and Steel Institute in 1948, had reviewed most of them, and those which were, for one reason or another, unsatisfactory could be at once eliminated. Of the remainder, the most important was that of G. Sachs, and E. A. Davis's and S. J. Dokos's modification of it, and the recent theory of R. Hills and S. J. Tupper. It was considered that the theory of Davis and Dokos could be used to obtain reasonably reliable values of the coefficient of friction under certain experimental conditions. Experiments with "back-pull" had shown that the relationship between the die load and the back-pull was not strictly linear, the small deviation from linearity being due to the fact that the coefficient of friction decreased as the back-pull was increased. In spite of this, however, it was believed that MacLellan's back-pull equation could be used to obtain accurate values of the coefficient under specified conditions. The effects on friction of a number of variables had been investigated using a variety of lubricants. Of these, the soaps provided relatively thick-film or "quasi-hydrodynamic" lubrication, and even the liquid lubricants showed some hydrodynamic tendencies.

The only speaker in the discussion, Professor H. Ford, said that until lately investigation into the plastic deformation in industrial metal-working processes had run along distinctly separate lines. It was now clear that a comparative study at an earlier stage would have speeded up the general progress now being made, certainly as far as cold-working processes were concerned. If the points of similarity in such processes as wiredrawing, cold rolling and deep drawing were considered, it was apparent that, in attempting an analysis of the forces involved and the nature of the deformation occurring, two fundamental qualities were concerned, namely, the stress-strain curve connecting the current yield stress with the corresponding amount of strain reckoned from the initial condition of the material being deformed; and the coefficient of friction between the deforming metal and the die or roll. Unfortunately, no direct way of measuring the coefficient of friction was available at present. Quite recently, MacLellan, after a careful assessment of all the published data on drawing force and other quantities, had found that the coefficient of friction varied from 0·09 to 0·4. Such a coefficient of friction was meaningless. Until a few years ago, a similar "spread" of values was quoted in cold rolling, but, both in rolling and deep drawing, the latest studies had narrowed the range to between 0·04 and 0·1 for the whole range of lubricants and surface finishes. The wiredrawing process, giving such vastly different values, had been the black sheep of the family, and had cast doubts on the much lower values found in other processes. The authors had been able to show that the coefficient determined as the empirical adjusting factor, assuming the drawing force and the yield-stress curve to be known, now came into line with other investigations. This paper, therefore, gave a definite indication that investigators were, in fact, chasing a real coefficient of friction and not just deriving an empirical coefficient. It would seem that the results given yielded an average coefficient of friction of 0·053 when using a good lubricant; a value agreeing very well with the range of 0·05 to 0·06 found in cold rolling and deep drawing. The "scatter" of the results, however, was rather greater than in other processes.

Professor Thompson, in the course of his reply, said that it was interesting to note the manner in which the values obtained for the coefficients of friction in different metal-working processes were coming together. Wiredrawing, however, was still, in some respects, in a class by itself.

WROUGHT ALUMINIUM-ZINC-MAGNESIUM ALLOYS.

The second paper considered was by Dr. Maurice Cook, Mr. R. Chadwick and Mr. N. B. Muir, of Imperial Chemical Industries, Limited, Metals Division, Birmingham. It was entitled "Observations on Some Wrought Aluminium-Zinc-Magnesium Alloys," and was presented by Dr. Cook. The authors stated that they had investigated high-strength aluminium-zinc-magnesium wrought alloys containing up to 12 per cent. of zinc, 3·5 per cent. of magnesium and 3 per cent. of copper, as well as chromium, manganese, iron, and silicon in amounts of less than 1 per cent. each. The object of the investigation had been to establish the most suitable range of compositions for bulk manufacture. Macro- and micro-structures, mechanical properties, resistance to corrosion, and thermal treatments had been studied on materials produced on an experimental scale. In addition, the freezing characteristics of the alloys had been investigated to ascertain compositions having small eutectic contents and, hence, desirable casting properties. As a result of these studies, limiting compositions had been established for alloys which possessed optimum mechanical properties and corrosion resistance, together with the desired freezing characteristics.

A comparison had then been made, under manufacturing conditions, of the casting and extrusion characteristics of two alloys having similar mechanical properties in the wrought condition, the one having a small and the other a large eutectic content. The superiority of the former, from the point of view of casting and working, was confirmed. This alloy had the following nominal percentage composition: 6·5 zinc, 1·8 magnesium, 1·5 copper, 0·25 manganese, 0·25 chromium, and the remainder aluminium. Further observations on the effect of different heat-treatment procedures had been made on an alloy of similar composition produced on a manufacturing scale in the form of rolled sheet. On this material the effects of cold work and secondary heat treatment had also been investigated to establish conditions for developing maximum corrosion-resistance compatible with high strength and a reasonable measure of ductility.

Dr. R. T. Parker, who opened the discussion, stated that he would ask the authors to admit the importance of copper as a major alloying constituent in the alloys by describing them as aluminium-zinc-magnesium-copper alloys. With regard to added elements, more information might have been obtained from silicon contents of 0·1, 0·2 and 0·3 per cent. and chromium contents of zero, 0·15 and 0·25 per cent. With the higher chromium contents, in particular, difficulty was likely to arise on account of the formation of intermetallic compounds of some size which might invalidate some of the observations made on corrosion resistance, for example. While on the subject of corrosion resistance, he felt that he must query the use of the accelerated testing medium. The authors had said that it was the standard medium which simulated prolonged exposure to marine conditions, but was that indeed the case? Had they any correlation to offer of their tests against long-time marine exposure? Probably, however, the most important point upon which he disagreed with the authors was in regard to their belief that the amount of eutectic had some bearing upon the casting properties of these alloys. In the casting of this type of alloy he believed that the cracking which took place was essentially "cold-cracking," and, as such, could only be related to stresses formed in casting and the presence of a brittle structure. Cracking in casting could be correlated with the composition as regards some of the major elements, zinc and magnesium for example, and some of the minor elements, such as silicon. Unless the authors could relate the presence of their eutectics with the brittle structure necessary for cold cracking, he must disagree with them.

Mr. H. W. L. Phillips desired to know what effect the present work would have on that of the welding research team at the University of Birmingham. The next speaker, Dr. I. G. Slater, spoke on the usefulness of corrosion tests and stated that the significance of laboratory corrosion tests was much over-estimated. It was time that "a return was made to nature" in corrosion testing. The authors had not referred to the directional properties of the alloys, which were notable if not notorious. When evaluating the mechanical properties of their alloys the authors had confined themselves to the proof stress, ultimate strength, and elongation values. Had they considered other values? The authors had done some work on extrusion. He had always thought that the extrusion speeds of these alloys were slow, but the authors had given the speed as 22 ft. per minute and he would like to know if such speeds applied in the case of simple or in those of rather more complex sections.

Mr. Christopher Smith asked if there was any likelihood of an alloy of aluminium being found which would be suitable for all purposes. The segregation of chromium, when this element was present above certain limits, was indeed a problem. Using material which contained 0·2 per cent. of this metal, his firm, Messrs. James Booth and Company, Limited, produced 16-in. diameter "billets" by casting. These were extruded to 12-in. diameter bar and then forged down to 3-in. diameter rods. There was evidence of very extensive "coring" in the alloy after heat treatment. In the absence of chromium, the alloy became homogeneous fairly easily but rather considerable variety occurred in the grain size. The next speaker was the President, Professor A. J. Murphy, who stated that the alloys now under discussion had been known for several decades. In fact, they had been mentioned in the 11th report of the Alloys Research Committee of 1921. Dr. W. Rosenhain and others had shown that, in alloys of aluminium-zinc-magnesium, spontaneous cracking occurred. The question was whether the authors could state that this material was now fundamentally free from this trouble. In answer to this, Mr. Christopher Smith said that the industry as a whole possessed considerable knowledge of the potentialities of these alloys. It was perfectly well known that certain things could be done with them, and done quite safely, while it was equally well known that for other purposes they were not suitable. After all, 70 : 30 brass was a material which normally behaved in a perfectly satisfactory manner, but, in certain circumstances, spontaneous cracking could occur.

Mr. Chadwick replied to the discussion and stated that various speakers had drawn attention to the bad and the good effects associated with the presence of chromium in the alloy. Both Dr. Parker and Dr. Slater had stated that slower and more "natural" methods of making corrosion tests were needed. Everyone would agree with them, but "natural" tests might take years and the results might vary according to whether the summers were dry or wet. Accelerated tests gave reproducible results, and to deal with a number of elements in a reasonable time it seemed that the only solution was to adopt an accelerated test. This did show up differences in specimens and enabled the corrosion-resistance properties to be interpreted. The possibility of doing without chromium in these alloys was a doubtful question. This element was of importance in connection with stress corrosion. Dr. Slater had criticised their method of evaluating mechanical properties, but he had not suggested alternatives. Mr. Christopher Smith had asked whether it was likely that an alloy suitable for all purposes would be found. It was, in his (Mr. Chadwick's) opinion, necessary to make slight changes in alloys to fit them for certain applications. Coring and the difficulty of obtaining a homogenised structure had been mentioned. They had found that small additions of titanium to alloys containing chromium enabled a homogeneous structure to be obtained. In answer to the President, these alloys did not show the tendency to spontaneous cracking to which he had referred. A selected alloy containing 6·75 per cent. of zinc, 1·75 per cent. of magnesium, 1·5 per cent. of copper, 0·25 per cent. of manganese, 0·25 per cent. of chromium, 0·2 per cent. of iron, and 0·15 per cent. of silicon, was capable of withstanding successfully stress-corrosion up to between 80 and 90 per cent. of its proof-stress figure. Dr. Maurice Cook, who also replied, said that while he agreed that the present alloys had been known for several decades, it was only in the last 10 years that they had been developed as commercial materials. The criticism of their accelerated corrosion test had been somewhat unfair and unreasonable. Tests of this type were both well known and well established. They were not meant to be exhaustive but they did give consistent and reproducible results.

ALUMINIUM-COPPER-TITANIUM AND CADMIUM ALLOYS.

The last two papers on the agenda were discussed jointly after presentation. Both were by Dr. H. K. Hardy, of the Fulmer Research Institute, Stoke Poges, and the first was entitled "The Effect of Small Quantities of Cd, In, Sn, Sb, Tl, Pb, or Bi on the Ageing Characteristics of Cast and Heat-Treated Aluminium-4 per cent. Copper-0·15 per cent. Titanium Alloy." The second paper dealt with "The Tensile Properties of Heat-Treated Aluminium-Copper and Aluminium-Copper-Cadmium Alloys of Commercial Purity."

When presenting his first paper, Dr. Hardy stated that small quantities, of the order of 0·5 per cent., of the slightly-soluble elements, cadmium, indium or tin had a definite influence on the course of precipitation of copper in aluminium. The natural ageing was depressed, but the rate of artificial ageing was accelerated by a factor between 3 and 8. Both the response to artificial ageing and the absolute strength were increased. The insoluble elements, antimony, thallium, lead and bismuth, had no influence on the ageing of the aluminium-copper alloy, although the bismuth particles mechanically reduced the strength properties. Very small additions of magnesium, of the order of 0·06 per cent., greatly diminished the influence of indium or tin, but did not affect the alloys containing cadmium. The quantity of magnesium required to neutralise the influence of indium or tin was approximately twice the ratio for the hypothetical compound Mg_2In or the stable compound Mg_2Sn. The results had important practical implications, since they pointed the way to improved and controlled properties for commercial-purity aluminium-copper alloys.

In the course of his second paper, Dr. H. K. Hardy stated that a previous research, presented to the Institute of Metals in 1950, had shown that additions of cadmium accelerated the artificial ageing and markedly increased the strength properties of cast and heat-treated aluminium-4 per cent. copper-0·15 per cent. titanium alloys of very high purity. Aluminium-copper-cadmium alloys of normal purity had now been examined in the cast or wrought condition. Alloys containing more than 0·1 per cent. of cadmium were hot-short and generally failed to forge. The quantity of cadmium was not critical in the case of cast alloys, and up to 0·5 per cent. had no detrimental effect on the ductility of fully heat-treated test bars at room temperature. Cadmium additions increased the strength properties of artificially-aged aluminium-copper alloys to an important extent and slightly improved the resistance to corrosion by salt spray. Such alloys merited consideration for industrial use. The effect of cadmium was not influenced by the presence of iron, silicon, manganese, zinc, nickel, or 0·05 per cent. magnesium. Cadmium additions did not affect the ageing, at 132 deg. C., of wrought aluminium-zinc-magnesium and aluminium-zinc-magnesium-copper alloys.

Professor A. von Zeerleder, who opened the discussion, stated that in the first paper Dr. Hardy had discarded the possibility that Cd, In and Sn had a hardening effect of their own by causing the formation of a new phase. He agreed with the author that these elements were rather influencing the hardening reaction of copper which, according to Dr. Hardy, occurred either by affecting the rate of diffusion of the copper or the rate of nucleation. In 1926, investigations similar to those described in the second paper had been carried out. Aluminium-copper casting alloys containing 0·2 per cent. magnesium (Alufont II) did not show any increased hardening effect after an addition of 0·05 per cent. Cd, even after ageing at 160 deg. C. Wrought alloys behaved similarly. Later investigations with increased cadmium content, however, had shown an acceleration of artificial ageing. For instance, an addition of 0·2 per cent. cadmium resulted in a remarkable increase in mechanical properties after 6 hours of artificial ageing at 140 deg. C. No increases were noticed with alloys of higher cadmium content. An addition of Cd to Al-Mg-Si alloys gave an increase of strength with no detriment to corrosion resistance. Working difficulties, at the time, had prevented the commercial application of these alloys. With the better working equipment at present available, however, alloys of this type were now welcome additions in engineering works.

Dr. J. C. Chaston considered that the papers were rather in the nature of a preliminary survey and it would be easier to discuss the properties and behaviour of these alloys when they had been studied in greater detail and when rather more data were available. Mr. H. W. L. Phillips, who spoke next, stated that machining properties and such matters as the shape of the chips obtained in machining operations had been correlated with the structures of alloys. He wondered whether the various additions to the author's alloys impaired machining properties and whether the shape of the chips would show this. The next speaker, Mr. E. A. G. Liddiard, said that the statement in the synopsis of the author's second paper that alloys containing more than 0·1 per cent. of cadmium were hot short and generally failed to forge was misleading; 0·1 per cent. was not the upper limit. All that had been established was that 0·1 per cent. cadmium alloys were not hot-short, whereas 0·25 per cent. cadmium alloys were. No other alloys had been studied within this gap of 0·1 and 0·25 per cent., so that it could only be stated that the limit for hot-shortness lay somewhere above 0·1 and below 0·25 per cent. Mr. R. Chadwick, who closed the discussion, stated that the author's work on the effect of cadmium additions on the corrosion resistance of wrought aluminium-4·5 per cent. copper alloys containing various iron and manganese additions had resulted in reductions in the maximum-stress values of between 1·2 and 4·3 tons per square inch. Such figures were of little value. Finally, he would like to know in what way the author considered that aluminium-copper-cadmium alloys were better than aluminium-copper-magnesium alloys.

In the course of his reply, Dr. Hardy stated that cadmium improved the machining characteristics of the alloys studied, although he had no information on the subject of the shape of chips. The figures for reduction in maximum stress value quoted by Mr. Chadwick were average values. The aluminium-copper-cadmium alloys were better than the aluminium-copper-magnesium alloys not only from the point of view of better machinability but they forged much better and their natural ageing characteristics were negligible.

The afternoon of Tuesday, September 18, was spent on visits to works in and around Venice. In the evening, a joint banquet of the Associazione Italiana di Metallurgia and the Institute of Metals was held at the Grand Hôtel des Bains, on the Lido. On Wednesday, the members were divided into eight groups, the first of which consisted of those returning direct to London. Members in group 2 left Venice for visits to steel and non-ferrous metal works in Milan. Members in group 3 visited works at Piave and Bolzano, as well as Milan, and those in group 4 works in Turin, as well as in Milan. The works and other tours for those in group 5 included visits in the vicinity of Florence; for members in group 6, in the neighbourhoods of Milan and Florence; for those in group 7, Bolzano, Milan and Florence; and for members in group 8, Milan, Turin and Florence.

SOLVING BEAM PROBLEMS BY RELAXATION METHODS.

By R. C. Coates, B.Sc. (Eng.), A.M.I.C.E.

Relaxation methods, originated by Professor (now Sir) Richard Southwell when he was at the University of Oxford, may be used in many problems encountered in engineering mathematics. They may be readily applied to problems involving the deflected shape of beams. In this instance, as in other applications of relaxation methods, the process is self-checking, and a lack of uniformity in the cross-section of the member under consideration adds little to the labour involved. The final answers are obtained as the deflections of a number of selected points, and any required accuracy may be obtained by a suitable choice of those points.

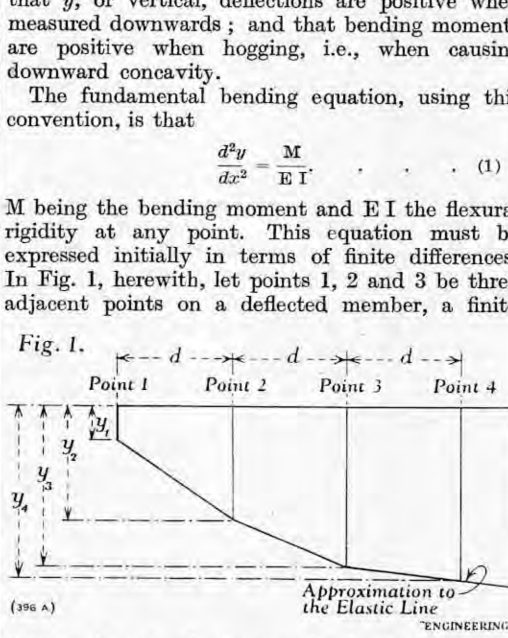
Throughout this article, the following conventions of sign will be adopted: that x, or horizontal, distances are positive when measured to the right; that y, or vertical, deflections are positive when measured downwards; and that bending moments are positive when hogging, i.e., when causing downward concavity.

The fundamental bending equation, using this convention, is that

$$\frac{d^2y}{dx^2} = \frac{M}{EI}. \quad . \quad . \quad . \quad (1)$$

M being the bending moment and E I the flexural rigidity at any point. This equation must be expressed initially in terms of finite differences. In Fig. 1, herewith, let points 1, 2 and 3 be three adjacent points on a deflected member, a finite

Fig. 1.



distance d apart. Let y_1 y_2 and y_3 be the deflections of these three points. Then the average slope between 1 and $2 = \frac{y_2 - y_1}{d}$; the average slope between 2 and $3 = \frac{y_3 - y_2}{d}$; and the rate of change of slope 1-2, $2\text{-}3 = \frac{1}{d}\left(\frac{y_3 - y_2}{d} - \frac{y_2 - y_1}{d}\right)$

$$= \frac{1}{d^2}(y_3 + y_1 - 2y_2) = \frac{d^2y}{dx^2}.$$

Substituting this value in the fundamental equation,

$$y_3 + y_1 - 2y_2 - \frac{M\,d^2}{EI} = 0. \quad . \quad . \quad (2)$$

Any number of points, a convenient distance d apart, could be selected on a loaded beam A B, Fig. 2, opposite, and an equation of form (2) written down for each point. The values of the actual deflections of each point might then be obtained by solution of the resulting series of simultaneous equations; but, since a large number of points must be used to obtain a true picture of the deflected member, and since the labour of solution of simultaneous equations increases with the number of unknowns, the relaxation process gives a simpler method of attack.

Essentially, the process allows one point at a time to move towards its final equilibrium position, and, therefore, at any stage, the equation (2) will not be completely satisfied. In general, therefore, the equation (2) should be rewritten to read

$$y_3 + y_1 - 2\,y_2 - \frac{M\,d^2}{EI} = R, \quad . \quad . \quad (3)$$

where R is the residual. The aim of the relaxation process is to reduce this residual to zero, or, to be precise, to make the residual so small that it may be neglected.

Any guess may be made originally for the values of y at the selected points. If these be initially assumed to be zero, that is, if the beam be initially assumed straight, then the value of R at any point will be given by $R = -\frac{M\,d^2}{EI}$, from equation (3). Again, from equation (3), if y_1 and y_3 be maintained constant, but y_2 allowed to increase, the change in the residual R may be calculated, since

$$\delta R = \frac{\partial R}{\partial y_2}\,\delta y_2 = -\,2\,\delta\,y_2.$$

It follows, therefore, that an increase of $\frac{R}{2}$ in the deflection at the point 2 tends to reduce to zero the residual at that point. It causes an increase of $\frac{R}{2}$, however, in the residuals at points 1 and 3; this may be seen by substitution of the new value of y_2 in the similar equations to (3) pertaining to the points 1 and 3. These residuals, likewise, must be reduced in magnitude, the reductions and carry-over being continued until the resulting residuals are sufficiently small to be neglected.

Removal of residuals may also be effected by "block relaxation," in which process a number of points are allowed to deflect simultaneously. In this case, it follows from equation (3) that, if y_2 and y_3 increase together by an amount $\delta\,y$, the change in R may be calculated, since

$$\delta R = \frac{\partial R}{\partial y_2}\,\delta y + \frac{\partial R}{\partial y_3}\,\delta y = -\,\delta y.$$

That is, an increase in y_2 and y_3 of R cancels the residual R at both points 2 and 3, and causes an increase of R in the residuals at points 1 and 4.

The complete relaxation table for the beam in Fig. 2 is shown, the original residuals at any point being shown to the right of the line drawn vertically through that point. For clarity, the distance d, and the value of the flexural rigidity E I have both been assumed as unity, the initial residual being calculated on the assumption that the beam had not deflected. When any residual has been altered, or removed, a cancellation mark has been introduced. The steps in the relaxation table are: (a) relaxation of point 2; (b) point 3; (c) point 1; (d) points 2, 3, 4; and (e) points 1, 2, 3, 4, 5, etc. The solution, shorn of the relaxation table, is given in Fig. 3, opposite, for a point-loaded non-prismatic beam. No difference in method is necessary, but account must be taken of the values of flexural rigidity when calculating residuals.

It should be noted that the completed solutions for the beams should satisfy equation (2); that is, the residuals using these calculated values of the deflection should be zero. The process extends to the cancellation of residuals down to those of unit magnitude, and agreement with equation (2) has been obtained to this degree of accuracy. If the weight of the beam itself is considerable, and non-uniform, as in the case of the whirling speed of a turbine rotor, an extension of the method may be employed for finding the deflection. Writing w for the weight per unit length of the beam, the equation becomes

$$\frac{d^2M}{dx^2} = w,$$

and this may be solved by the foregoing relaxation method, the resulting bending-moment values being divided by the flexural rigidity at each point to give the initial residuals for a second relaxation calculation leading to the elastic line.

By the introduction of "fictitious nodes" at the ends of the beam, and the use of a theorem due to Mueller-Breslau, the influence line for fixed-end moments in a beam with haunches has been obtained. By means of that theorem, it may be proved that the deflected shape of a fixed beam, produced by unit rotation at one end, gives directly the influence line for fixing moment at that end.

The beam is first loaded with the bending-moment diagram produced on a simply supported span A B by a couple at A, as shown in Fig. 4, opposite. The beam is imagined supported at points F_A and F_B; that is, at fictitious nodes a distance d beyond the ends A and B, being extended beyond A and B by rigid arms. The normal relaxation process gives the deflected shape of this simply-supported beam under the action of the loading. Corrections are now necessary as follows:—(a) correction of the deflected shape to a base line

RELAXATION METHODS IN BEAM PROBLEMS.

Fig. 2.

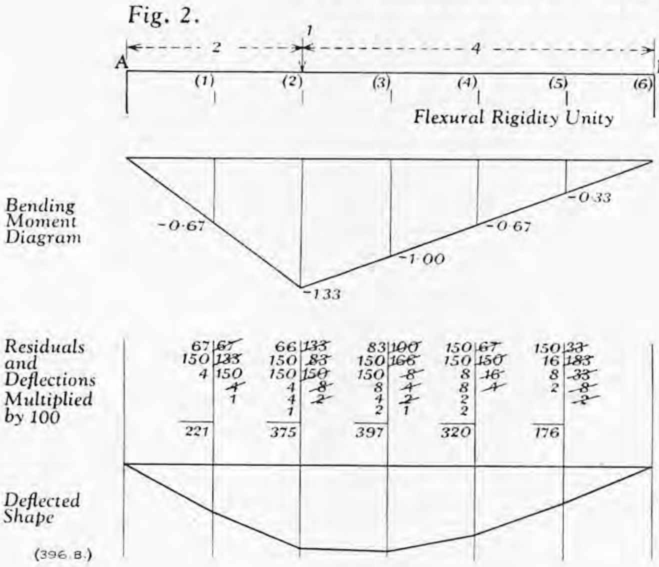


Fig. 3.

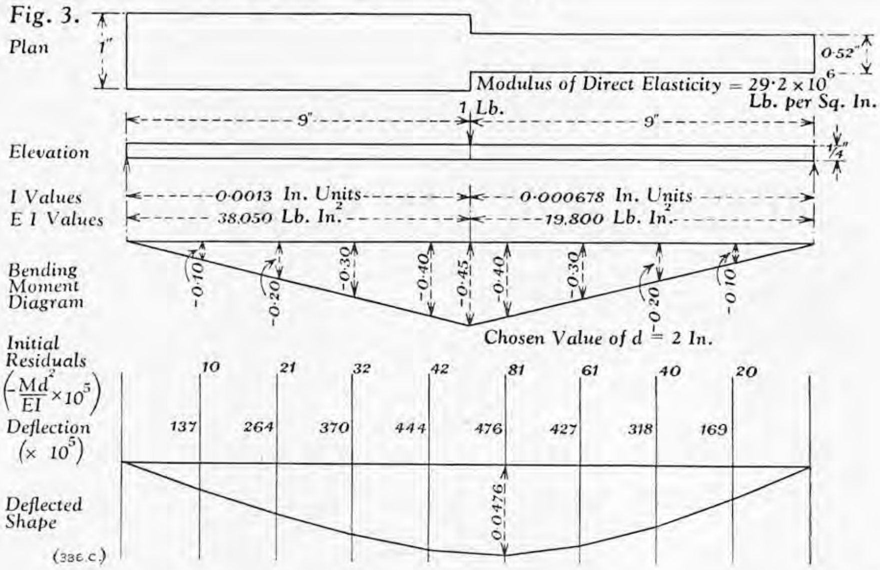
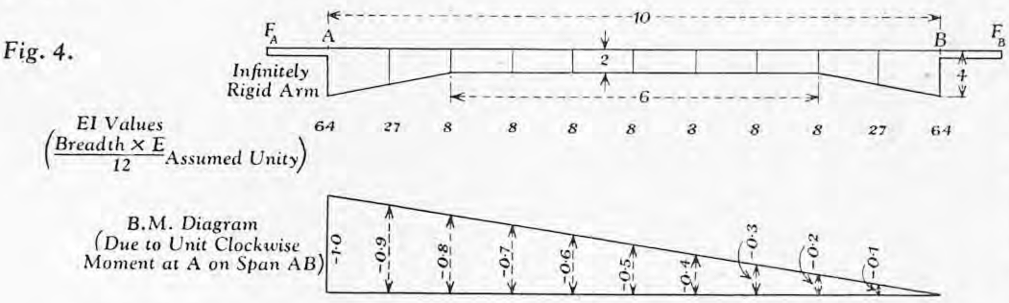


Fig. 4.



Initial Residuals $\left(-\frac{Md^2}{EI}\times 10^4\right)$	0	156	333	1,000	875	750	625	500	375	250	125	0	0
Solution	0	2,944	5,732	8,187	9,587	10,112	9,895	9,053	7,711	5,995	4,029	2,014	0
Correction (a) to Base Through AB: Subtract y_B	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014	-2,014
	-2,014	930	3,718	6,173	7,573	8,098	7,881	7,039	5,697	3,981	2,015	0	-2,014
Rotate About B	-1,023	-930	-837	-744	-651	-558	-465	-372	-279	-186	-93	0	+ 93
	-3,037	0	2,881	5,429	6,922	7,540	7,416	6,667	5,418	3,795	1,922	0	-1,921
Correction (b) (Apply Moment at B to make Slope Zero at B)	1,215	0	-1,216	-2,400	-3,427	-4,217	-4,691	-4,769	-4,378	-3,434	-1,822	0	1,921
	-1,822	0	1,665	3,029	3,495	3,323	2,725	1,898	1,040	360	100	0	0
Final Value (After Correction (c) to Make Unity Slope at A)	-1,000	0	914	1,662	1,918	1,824	1,496	1,042	571	198	55	0	0
Column Analogy Values × 10^4		0	939	1,668	1,973	1,884	1,533	1,048	560	198	39	0	

(396.D) "ENGINEERING"

passing through A and B, that is, making the deflection zero at those points; (*b*) correction for the slope at B, making the line BF_B of zero slope; and (*c*) correction for the slope at A, making the line AF_A of unity slope. These successive stages are shown in Fig. 4, where the final results are tabulated and the completed influence line plotted. For comparison, the bottom line of the table shows values of the influence-line ordinates obtained by a laborious calculation, using the column analogy method of Hardy Cross.

COMMONWEALTH CONFERENCE ON OPERATING GAS-TURBINE AIRCRAFT.—A conference of representatives of the Commonwealth and Colonial governments was held in London from September 25 to October 5, to consider the problems of operating aircraft propelled by gas turbines. It was concluded that the Comet could be operated practically with existing facilities, but that to realise its full commercial capabilities some improvements would be required. Radio sonde and radar wind stations for forecasting wind and temperature at heights up to 50,000 ft. should be extended. Improved radar and radio navigational aids will be required, to give accurate position-indication over medium distance. A new long-distance navigational aid will have to be developed. Improvements to fixed ground communications, already agreed internationally, should be effected quickly. Turbine-propelled aircraft, the Conference concluded, can be operated satisfactorily from runways designed for piston engined aircraft of comparable size. It was considered that facilities suitable for jet-propelled aeroplanes would be more than adequate for aircraft propelled by propeller turbines.

CHAPMAN'S LOCOMOTIVES, 1812-1815.*

By E. A. FORWARD, A.R.C.S., M.I.Mech.E.

WILLIAM CHAPMAN of Newcastle (1749-1832) was well known as a civil engineer; but, while his biographers concentrate on his work in connection with canals, with some mention of his "drops" for minimising the breakage of coal during shipment, little is said about his essays in locomotive construction, which commenced in 1812.

Early writers on locomotive history mention his patent of December 30, 1812, and the trial of his chain-haulage engine at Heaton Colliery about October, 1813, describing it generally as a costly failure; they usually omit to mention what may be regarded as the more important part of his invention, namely, the reduction of the load per wheel by placing the engine on six or eight wheels, and arranging for the mechanical equalisation of the load on those wheels by mounting the axles in pairs in swivelling trucks, since called "bogies," so as to facilitate their passage round curves, and so to counteract the disadvantages of a long wheelbase. It is known that an eight-wheeled engine of this kind was made for Chapman by Phineas Crowther of the Ouseburn Foundry, Newcastle, and was tried at the Lambton Colliery on December 21, 1814.

Considering that very few railway locomotive experiments had taken place before the date of Chapman's patent application, he must have been a man of remarkable prescience to have envisaged the requirements of a practicable locomotive and the probable results of the application of his ideas, when he can have had little practical experience to guide him. There is, however, a suggestion, dating from 1861, that Chapman had made experiments with a locomotive as early as 1805; if so, it is probable that this was the Trevithick locomotive made by John Whinfield of Gateshead in that year. The previous experiments were made with the three Trevithick locomotives, namely, the Penydarran engine of 1804, the Newcastle engine of 1805, and the London locomotive of 1808; followed by the Blenkinsop rack locomotives at Leeds, which commenced working in June, 1812. The first and third of these ran on cast-iron plate-ways, and it is recorded that their weight was too great for the rails when supported upon stone blocks in the way then usual. Trevithick said that the Penydarran locomotive weighed about 5 tons; his London engine weighed 8 tons. The Newcastle locomotive of 1805 is said to have been intended to run on the wooden railway at Wylam Colliery, and its weight is given by a contemporary witness as 4½ tons; yet it also, according to John Buddle, was too heavy for the rails.

It may be presumed that Chapman saw this engine in 1805, and he may have learned about the Penydarran trials from Whinfield, who had been agent for Trevithick's high-pressure stationary engines since 1803. It is possible that Chapman himself saw the London locomotive of 1808, or heard of it from John Buddle, who had met Trevithick in London in April, 1808. Trevithick, with his London locomotive, overcame the track weakness by laying his plate-rails on longitudinal timber baulks, so that they had a continuous support, and this arrangement sustained the 8-ton load, though the rails themselves were probably quite light. Blenkinsop's first rack-rail locomotives of June, 1812, weighed between 4 tons and 5 tons, and even for that weight, Matthew Murray said in 1813, the cast-iron edge rails had to be strengthened to carry them.

It must be supposed that by December, 1812, Chapman knew a good deal about these earlier experiments, and was, no doubt, impressed by the fact, demonstrated by Trevithick in 1804, that an adhesion locomotive of the necessary power and weight to haul a paying load was too heavy for the existing tracks. He would appreciate also that Blenkinsop's rack system was devised to enable an engine of small weight to haul greater loads than could be hauled by an adhesion engine of the same weight, or to surmount steeper gradients with a given load. Chapman's ideas as to how these conditions could be met are best described in the Patent Specification (No. 3632), applied for on December 30, 1812, in the names of "William Chapman of Murton House in the County of Durham, Civil Engineer, and Edward Walton Chapman, of Willington Ropery, in the Parish of Wallsend, in the County of Northumberland, Ropemaker," entitled "A Method of Facilitating the Means and Reducing the Expence of Carriage on Railways and other Roads." The Specification was enrolled on February 27, 1813, and runs as follows:—

"Our said Invention doth chiefly consist in the use of a chain or other flexible and continuous substance stretched along the road to be travelled, properly secured at each end and at suitable intervals, and in the application of this chain round or partially round a barrel or grooved wheel in such a manner as not to slip; when this grooved wheel, which is fixed upon, before, or behind, a carriage supporting or containing any internal self-moving power, shall be put in motion by the said power, so that by the revolution of the barrel or grooved wheel round its axis, either one way

* Paper read before the Newcomen Society at a meeting held in London on October 10, 1951. Abridged.

or the other, it shall necessarily draw the said carriage and any others which may be attached to it within its powers of action. We also, as the carriage containing the motive power will, thus loaded, be too heavy in various cases for the strength of the existing iron or wooden rails, if resting on four wheels only, so arrange for such ways (or other confined ways, where the ledges either of the ways or of the wheels regulate the direction of the carriage) that it may rest equally and move freely round curves or angles either on six or eight wheels so as to reduce its pressure on each in the inverse proportion of its number of wheels."

In Fig. I of the drawings attached to the Specification, the locomotive is represented by a rectangular outline on a frame supported by four small wheels which appear to run on a wooden track. At one end of the engine there is a large grooved wheel round which the chain passes, being guided thereto by two pulleys below the wheel, so that the chain will embrace as large an angle of the wheel as possible. Above these guide pulleys are two binding wheels, either of which can be made to press upon the chain by means of a counterweight, so as to keep it in contact with the wheel on the slack side and thus prevent the chain from slipping. The wheel groove is provided with projections against which the chain links catch. No supports for this chain gear are shown, or any engine mechanism to drive it. The chain is supported at intervals by forks firmly fixed in the middle of the track, so that the driving pull is taken by each in succession as the engine progresses, and engines could follow one another on the same chain without putting too great a stress on any part of it.

The next four pages of the Specification are taken up with a detailed description of the method of working the engine on single or double ways, and for transferring it from one chain to another at terminals, involving arrangements for separating the chain so as to remove it from its driving wheel. The whole method seems to be so inconvenient, that it may be considered almost impracticable for anything but providing a shuttle service on a single line.

The Specification drawing also shows a plan view of a six-wheeled engine frame described as follows :—

"Fig. VIII shows a carriage of six-wheels for the engine, which may rest equally, or nearly so, on each of its wheels, and move freely round the curves or past the angles of a railway, 1.1., the fore pair of wheels are, as usual, on railways, fixed to the body of the carriage. 2.2., and 3.3., the other two pair, are fixed (on axles parallel to each other) to a separate frame over which the body of the carriage should be so poised as that two-thirds of its weight should lie over the central point of the four wheels where the pivot 4 is placed, and the remaining third over the axis 1.1. The two-thirds weight of the carriage should rest on conical wheels or rollers, bearing upon the curved plates C.C., so as to admit the ledgers of the wheels or those of the way to guide them on its curves or past its angles, by forcing the transome or frame to turn on the pivot, and thus arrange the wheels to the course of the way, similarly to the carriage of a coal waggon. And if the weight of the locomotive engine should require eight wheels, it is only requisite to substitute in place of the axis 1.1. a transome such as described (laying the weight equally upon both), and then similarly to two coal waggons attached together, the whole four pair of wheels will arrange themselves to the curves of the railway.

"In using locomotive, steam or other engines for mines, there will be a want of draught for the fire under the boiler or air tubes, because of deficient height for the chimney or vertical flue, and also above ground, where necessary to pass under bridges for high roads, one, in these instances of want of draught, attaches to the locomotive engine the blowing apparatus of a common winnowing machine, to force a current of air under the bars of the fire-place, which apparatus should of course receive its motion from the engine."

Chapman then goes on to describe his method of using an endless chain of limited length for travelling an unlimited distance, but it appears doubtful whether it was ever tried. The specification concludes : "It is already known to the public that self-acting locomotive engines have been used for the purpose of drawing carriages after them. But the object of this specification is not to include as our Invention what has heretofore been publicly done or granted to any preceding Patentee, but simply to claim for the purposes explained, such position, application, and greater or less combination of the things mentioned, as falls within our description so far as such combination has neither been publickly carried into effect, or been included in the Specification of any prior Letters Patent, granted to any person or persons whomsoever."

Chapman, like Trevithick, had realised that the draught for the boiler might be insufficient with the allowable chimney height, and he adopted a fan to force air through the grate. Trevithick included, in his patent of 1802, an engine-worked bellows for such cases, though in practice he used the exhaust steam. From this specification, it may be said that Chapman's chain arrangement was, in effect, a variation of Blenkinsop's, inasmuch as the chain formed a kind of flexible rack. In addition, he had realised that reducing the weight per wheel of the engine by providing it with more wheels was not all that was required, as an engine having three or four axles running in fixed bearings, attached to a rigid frame, would have a quite indeterminate axle loading, depending on the state of the track. Thus, with a six-wheeled engine, the whole load might come on the middle axle on passing over a hump in the track. Chapman, therefore, sought to overcome this difficulty by devising a method of mechanically equalising the load on all the wheels. In the six-wheeled frame shown in the drawings, it would be essential for longitudinal equalisation that the independent frame carrying two axles should be free to tilt longitudinally with respect to the main frame, and this is ensured by conical rollers placed between the truck and main frames. Such an arrangement would, however, preclude any lateral equalisation, as the truck could not tilt laterally if both the cones were in contact. While the central pivot controlled the angular motion of the truck, it evidently carried no load. In fact, it would seem that Chapman, in his patent drawing, was content mainly with longitudinal equalisation of the load on each axle, and did not trouble about transverse equalisation of the load on the two wheels of each axle. His rigid four-wheeled truck would act like an ordinary waggon, in that, on an uneven track, the whole load might come on diagonally opposite wheels ; in the six-wheeled engine, two-thirds of the weight might come on two wheels only.

Chapman reprinted his specification in a pamphlet accompanied by some remarks, dated May 18, 1813, and with revised drawings. The contents of this pamphlet were published in the *Repertory of Arts* for February, 1814. The remarks, which are of historical importance, are as follows :—

"The plan, described in the preceding Specification, for reducing the expence of conveying coals along railways, will shortly be carried into execution on the waggon-way from Heaton colliery to the river Tyne. A principal feature in the advantage to be derived from the adoption of this patent is, that no alteration is required in the waggon-ways, whether of wood or iron ; because if strong enough to sustain the coal waggons which they necessarily must be, they will be amply capable of supporting the locomotive engine, when placed on six or eight wheels, accordingly as its weight may require ; and thus the alternative, hitherto laboured under, will be obviated, viz. either that of the weight of the engine destroying numerous rails, or the total renovation of the way, by laying new rails at a great charge. Any gentleman disposed to carry this plan into effect, will receive every requisite information, on applying to Messrs. Chapman & Buddle, Newcastle-upon-Tyne."

In the revised drawing of the engine, the plain rectangle for the boiler has been replaced by a one-piece cast-iron shell with ends bolted on. The wheels now have spokes and rims ; the chain wheel also is spoked, and it and the guide pulleys are mounted on a wooden framework. No indication is made of engine cylinders or means of driving the chainwheel. The six-wheeled frame has been made more complete by the addition of three massive cross-beams connecting the side frames of the track, the pivot being shown on the middle one. In the original specification the track appears to be formed of rectangular wooden rails showing no joints or sleepers. In the revised drawing, the wooden rails are in short lengths and appear to be faced with iron plates. At the date of this pamphlet, it may be supposed that the Heaton engine was under construction, so that possibly the alterations on the drawings represent something actually in being.

The name of John Buddle (1773-1843) in this pamphlet is taken to indicate some sort of partnership between Chapman and Buddle in the engine business, and is the first intimation we have that this most famous mining engineer, of his day, was interested in locomotives. Buddle was known as the "King of the Coal Trade," and is said to have attained an almost autocratic position, so that his support of Chapman's inventions would be of considerable value to the latter. It should be noted, moreover, that both the known Chapman engines were tried at collieries where Buddle was viewer or consultant.

There is no known contemporary newspaper account of the Heaton trial, but O. W. D. Hedley, in *Who Invented the Locomotive?*, published in 1858, said (without giving evidence) that the trial took place in October, 1813. He said, also, that he was informed that this engine was a costly failure.

In 1814, Sir John Sinclair issued a questionnaire respecting the conveyance of coals on railways by steam engines and two sets of replies that he received were published in the *Repertory of Arts*, vol. 33, 1818. The first set was correctly attributed to John Blenkinsop, but the second set, signed "J.B.," and dated Newcastle, October 5, 1814, though at variance with the first, was also attributed, in the published replies, to Blenkinsop ; no doubt, owing to the initials "J.B." being the same as Blenkinsop's.

In the Liverpool and Manchester Railway Centenary Exhibition, in 1930, there was a letter from Sinclair to Blenkinsop, dated October 23, 1814, thanking him for his replies to the queries. From this letter, it appears that Sinclair had not sent his questionnaire direct to Blenkinsop or other individuals, but had left copies with a Mr. Foster, of Newcastle, for distribution. We assume that Foster collected what replies he could get from interested parties, but obtained only those from Blenkinsop and Buddle, which he sent together to Sinclair, who presumably did not know that the author of the second set was a different person having the same initials ; hence the two sets were lumped together on publication.

As these replies contain the patentees' views at October 5, 1814, after the Heaton engine had been tried, the relevant portions may be quoted : "The Specification of the Patent consists wholly of the two following parts, viz. : (1) In reducing the relative weight of the locomotive on railways, by placing it either on six or eight wheels, that it may rest equally and move freely round the curves of the railroads, to which only that part of the invention extends. (2) In using a continuous chain stretched along the way and secured at the ends, which, by being passed over a grooved wheel (with iron Y's) attached to the frame of the engine, and moved by it, enables the locomotive machine to haul itself and its load up hill, as has been effectually proved under very disadvantageous circumstances on the wooden railway from Heaton colliery to the river Tyne. Whilst the machine for the road was constructing, further trials have been made on iron roads nearly level, by causing the locomotive engine to give motion to its travelling wheels according to Trevithick's principle, which in these cases have been found to answer uncommonly well, excepting as to the necessity either of strengthening the waggon-way rails, or of adopting Messrs. Chapman's mode of placing the engine on six or eight wheels. This plan is in use at Killingsworth Colliery, near Newcastle.

"In consequence of the efficacy of friction, or resistance to the slipping of the carriage wheels of locomotive engines, it will only be found necessary to place chains on the parts of railways materially ascending ; which at those parts can very quickly be laid over the grooved wheel, and the waggons when arrived at the upper end will disengage themselves, so as to proceed by friction alone. . . . A well-constructed locomotive with two eight-inch cylinders on Trevithick's principle, should draw 40 or 50 tons (waggons included) at the rate of four miles an hour on a level iron railway, and, up an ascent of one and a half inches to the yard, will hardly move at the rate of one and a half miles an hour with 40 tons, or not so fast."

In this statement, Buddle now gives priority to the multi-axle bogie engine over the chain-haulage device, and seems to envisage a combined chain and adhesion engine which should travel by adhesion on the level, or on small gradients, and by the chain, or both, on the steeper parts of the line. Buddle's reference to adhesion engines being successfully tried by October, 1814, might refer to Hedley's Wylam engine, to George Stephenson's Killingworth engine, the venue of which he mentions by name, or Chapman's Lambton engine, then under construction or possibly completed at that time. Nicholas Wood, writing in 1825, said that the Heaton chain-engine was abandoned owing to its great friction and liability to get out of order. Matthias Dunn, who had worked under Buddle, and may have had personal knowledge of Chapman's chain-engine at Heaton, contented himself by saying that the scheme "was not looked upon with much confidence."

(To be continued.)

BRITISH STANDARD SPECIFICATION.

The following publication of engineering interest has been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 24, Victoria-street, London, S.W.1, at the price quoted at the end of the paragraph.

Identification Scheme for Aircraft Pipelines.—A standard identification scheme for aircraft pipelines, B.S. No. M.23, has now been published. It has been prepared at the request of the Air Registration Board and approved for publication by the Aircraft Industry Standards Committee for the purpose of providing a scheme to indicate, on an international basis, the function of pipe systems in aircraft. Identification is provided by the combination of a written description of the main function of a pipeline and a series of geometric symbols suitable for international use. The scheme is independent of the utilisation of colour in order to avoid confusion with various existing colour codes. [Price 2s., postage included.]

THE HOLME MOSS TELEVISION STATION.

The Holme Moss television transmitting station of the British Broadcasting Corporation, which is to be formally opened by the Chairman (Lord Simon of Wythenshawe) to-day (Friday, October 12), is situated on the Yorkshire moors some 8 miles south of Huddersfield. The site, which covers an area of 150 acres, lies at an altitude of 1,750 ft., which, with the 750-ft. mast, brings the transmitting aerials to a height of 2,500 ft. above sea level. Holme Moss is, therefore, the highest of any of the British television stations, either existing or projected.

A general view of the station, with the main and auxiliary masts, is given in Fig. 5, on page 461. It comprises an L-shaped building, which has been designed to harmonise with the wild character of the surroundings. It was constructed by Messrs. John Laing and Son, Limited, London, N.W.7, the architects being Messrs. Wimperis, Simpson, Guthrie and Fyffe, 61, South Molton-street, London, W.1. One arm of the building houses the main vision and sound transmitters and the other a quality-checking room, offices and canteen. It has been built to retain as much heat as possible and is warmed either by waste heat from the transmitter-cooling equipment or from the thermostatically-controlled convectors. A separate building contains the stand-by transmitters, substation and garage. Supplies of water are obtained from the Yatcholme reservoir, some 800 ft. below the site, by two electrically-driven remote-controlled high-lift pumps.

The vision transmitter, which was constructed by Marconi's Wireless Telegraph Company, Limited, Chelmsford, has a peak white power of 45 kW and is claimed to be the most powerful in service. Its overall length is 31 ft., which includes a power distribution cubicle 10 ft. long. The equipment is contained in eight cubicles, which are arranged in line with the radio-frequency stages in order of increasing power from left to right, when viewed from the front; and the modulator stages from right to left. Thus, the radio-frequency output stage comes next to the final modulator stage. The radio-frequency section comprises a drive unit, consisting of a quartz-crystal oscillator working at one sixth of the carrier frequency of 51·75 megacycles (5·8 m.), followed by two stages of multiplication and an amplifier. Next come two low-power stages, which consist of push-pull amplifiers, using two and four tetrodes respectively. These are followed by a third radio-frequency amplifier, which comprises two air-cooled triodes arranged in a balanced-bridge circuit and hard driven, so as to stabilise the output voltage. In the subsequent cathode-follower stage the output is taken from an impedance, which is arranged between the cathodes of the two triodes and earth. The result is a low output impedance, so that the radio-frequency drive voltage to the final stage is almost independent of the input impedance. The final modulated output stage consists of two water-cooled thoriated-filament triodes in push-pull in a balanced-bridge linear wide-band amplifier. This stage is grid-modulated and is tuned by varying the characteristic of the parallel line element, which forms the anode circuit inductance. The impedance of this element is varied by altering the spacing between the two legs of the line. The output from this stage is coupled to the feeder through a wide-band coupling circuit and balance-to-unbalance radio-frequency transformer.

The first section of the modulator consists of a pre-amplifier. This accepts a vision signal with an overall amplitude of 0·7 volt and a picture-synchronising signal ratio of 70 to 30 in terms of the amplitude. This signal is amplified to 20 volts and its amplitude is rendered independent of variations in the amplitude of the incoming signals. The next section consists of a sub-modulator, comprising an amplifier and a cathode follower, both of which are of the shunt-regulated type. The input level is thereby raised from 20 to 150 volts, the output impedance being about 30 ohms. As the output impedance of a shunt-regulated amplifier is much lower than that of one of the conventional type, its band width is greater. The direct-current potentials of the grids of the regulator valves, which form the anode load of the amplifier valves, are adjusted by chains of series-connected neon stabiliser tubes. These offer practically zero impedance to alternating current, but have a constant direct-current potential drop across them. The chains are mounted on interchangeable units and are fitted with plugs, so that the correct number of tubes can be connected in circuit.

The output from the sub-modulator is fed to a " black level clamp," which also consists of a shunt-regulated cathode-follower. The grid of this follower is coupled to the sub-modulator and its output is transmitted to the final modulator unit. This cathode follower is " clamped " to the correct level during the black level period after the synchronising pulse. For this purpose two forms of clamp are used, each of which controls the black-level signal radiated by the transmitter, so that its variations with picture content are less than 1 per cent. If either of these methods should fail a simple arrangement of diodes can be switched in, although in this case the variations in black level will be noticeable to the critical observer.

The modulator unit, the final stage of which is illustrated in Fig. 2, on page 460, is supplied with an overall signal amplitude of 140 volts from the " clamp " and delivers a 1,200-volt signal to the grids of the radio-frequency amplifier. It comprises a shunt-regulated amplifier with two valves, followed by a shunt-regulated cathode-follower, containing six valves. All these

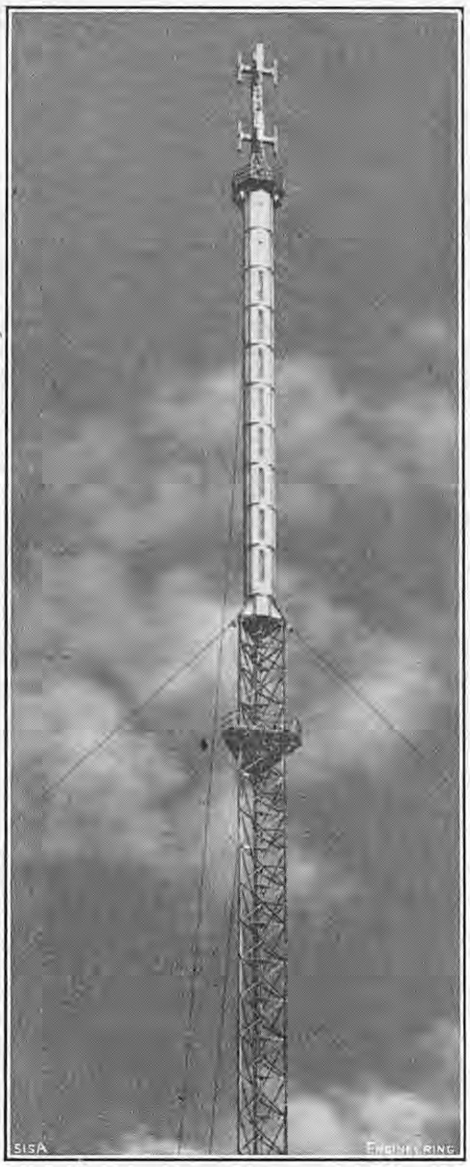


Fig. 1. Transmitting Aerial at Holme Moss.

valves are forced air-cooled triodes with indirectly-heated oxide-coated cathodes. They have a mutual conductance of about 20 mhos and a maximum anode dissipation of 2 kW. The modulator has an output impedance of about 5 ohms and is capable of dealing with the grid current of the radio-frequency stage, which varies from zero up to 3 amperes with the picture brightness. It can also deal with a capacitance load of about 400 picofarads, the current through which depends on the wave form of the picture.

The high-voltage power supply for the vision transmitter is obtained from hot-cathode mercury-vapour rectifiers. These rectifiers are, in turn, supplied from duplicate 11-kV feeders, laid by the British Electricity Authority, through two 500-kVA transformers, the secondary voltage of which is 415 volts. These transformers and the associated low-voltage switchgear were manufactured by the Brush Electrical Engineering Company, Limited, Loughborough. The phases of the 415-volt supply to the transmitter rectifiers are stabilised and phase-balanced by moving-coil voltage regulators. In addition, the high-voltage direct-current supplies, the output of which must be maintained constant, are provided with shunt-valve stabilisers, so that their output impedances are very low. The modulator is arranged to work at 3·5 kV with a current of 6 amperes and both its positive and negative terminals are insulated from earth. A stabiliser is provided to give this supply a source impedance of 0·5 ohm, while an additional stabiliser reduces the impedance between the negative terminal and earth to 0·16 ohm. These low source impedances are necessary owing to the fact that the varying grid current in the radio-frequency stage returns through this circuit, while the anode current in the modulator varies with the signal level. The filaments of the valves in the last three radio-frequency stages of the vision transmitter are supplied with direct-current from a motor-generator set, the voltage of which is maintained constant to within 1 per cent. by an electronic regulator. When starting from cold, the filament current is limited to 110 per cent. of normal. All the other valves in the transmitter are heated by alternating current.

The sound transmitter, which was also constructed by Messrs. Marconi's Wireless Telegraph Company, Limited, is similar to that installed at the Sutton Coldfield television station.* It has a carrier power of 12 kW and operates on a frequency of 48·25 megacycles. High-power Class B modulation with the usual negative feed-back circuits is employed, the result being that the total harmonic distortion is less than 2 per cent. at levels of modulation up to 95 per cent. over the normal range of modulating frequencies. The carrier noise level is also better than 60 decibels below 100 per cent. modulation. The drive unit and the first three radio-frequency amplifiers are similar to those on the vision transmitter. The fourth, and final, radio-frequency stage consists of a single air-cooled valve in an earthed grid coaxial-type circuit. This stage and the previous stage are both anode-modulated. It is necessary to modulate the penultimate stage since, with the grid of the final stage earthed, some of the power from it is fed to the aerial. The output from the final stage is passed through a filter to remove radio-frequency harmonics and then through a switch to the output combining unit, which is described below. The anode and bias supplies on the sound transmitter are obtained through rectifiers. All the valve filaments are heated by alternating current, except those in the modulated output stage. All the valves are air-cooled.

Each transmitter is provided with its own valve-cooling plant, the contractors for which were Messrs. Rosser and Russell, Limited, 30, Conduit-street, London, W.1. This plant is contained in separate rooms to isolate the noise and supplies air through an enclosed system until its temperature has been raised to a suitable value. The surplus warm air can then be either circulated round the building or exhausted to the atmosphere, the selection being determined by thermoelectrically-controlled motor-driven dampers. Distilled water, which has been pressurised by nitrogen at 5 lb. per square inch to exclude air, is circulated through the jackets of the valves in the modulated-output stage of the vision transmitter. The closed water circuit is cooled by air, which is then used for heating the building. Each transmitter is also provided with a water-cooled test load. A view of the cooler room for the vision transmitter, with the blowers for the final radio-frequency stage on the left, is given in Fig. 6, on page 461.

The vision transmitter supplies a double side-band signal. The upper side-band of this signal, however, is attenuated in a vestigial side-band filter, which is connected between the transmitter and the combining unit mentioned below. This filter comprises a high- and a low-pass section, the former terminating in a water-cooled absorber load, which dissipates about 1 kW when normal pictures are being transmitted; and the latter in the 51·5-ohm feeder which leads to the aerial. The lower-frequency side-band is thus transmitted fully, but the upper side-band is increasingly attenuated at vision frequencies above 0·75 megacycle. At 53·25 megacycles, which is the carrier frequency of the sound transmitter, the attenuation introduced by the filter is about 12 decibels.

The combining unit, which is illustrated in Fig. 3, page 460, consists of a balanced-bridge circuit to the opposite corners of which the outputs from the vision and sound transmitters are connected. Two of the opposing arms of this bridge are formed by the load on the coaxial feeder to the aerial and a wide-band resistance, respectively. The other two are formed by complementary networks, which present a low impedance at vision-carrier frequency and a high impedance at sound-carrier frequency; and *vice versa*. The power dissipated in the resistance load under working conditions is about 300 watts. The vision and sound signals are thus combined in the transmitter building, a more convenient arrangement than that employed at Sutton Coldfield where, it may be recalled, a diplexer at the top of the cylindrical section of the mast is used for this purpose.

The combined vision and sound outputs are transmitted to the aerial at the top of the mast through a concentric feeder. This feeder, which has an external diameter of 5 in., is built up in 12-ft. sections with an expansion joint every 150 ft. To prevent condensation,

* See Engineering, vol. 168, page 661 (1949).

HOLME MOSS TELEVISION STATION.

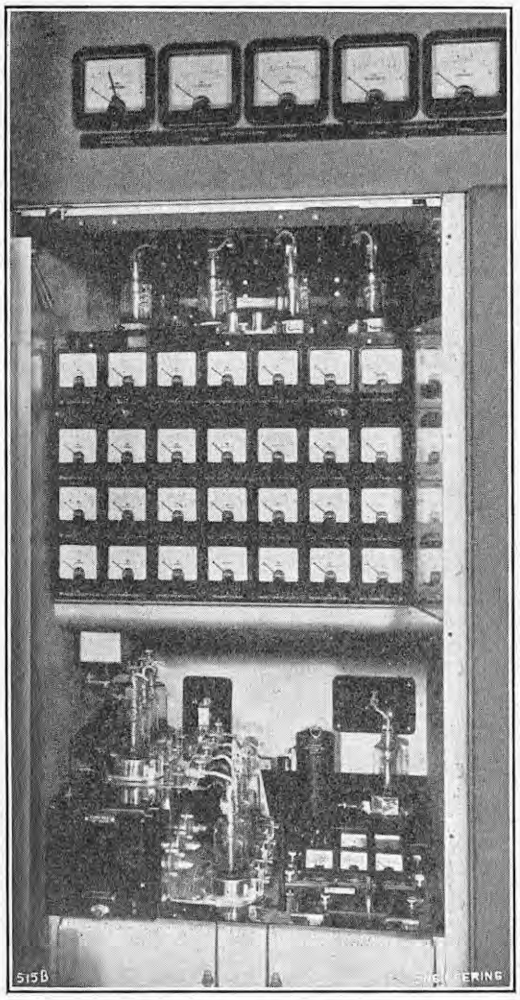


Fig. 2. Modulator of Vision Transmitter.

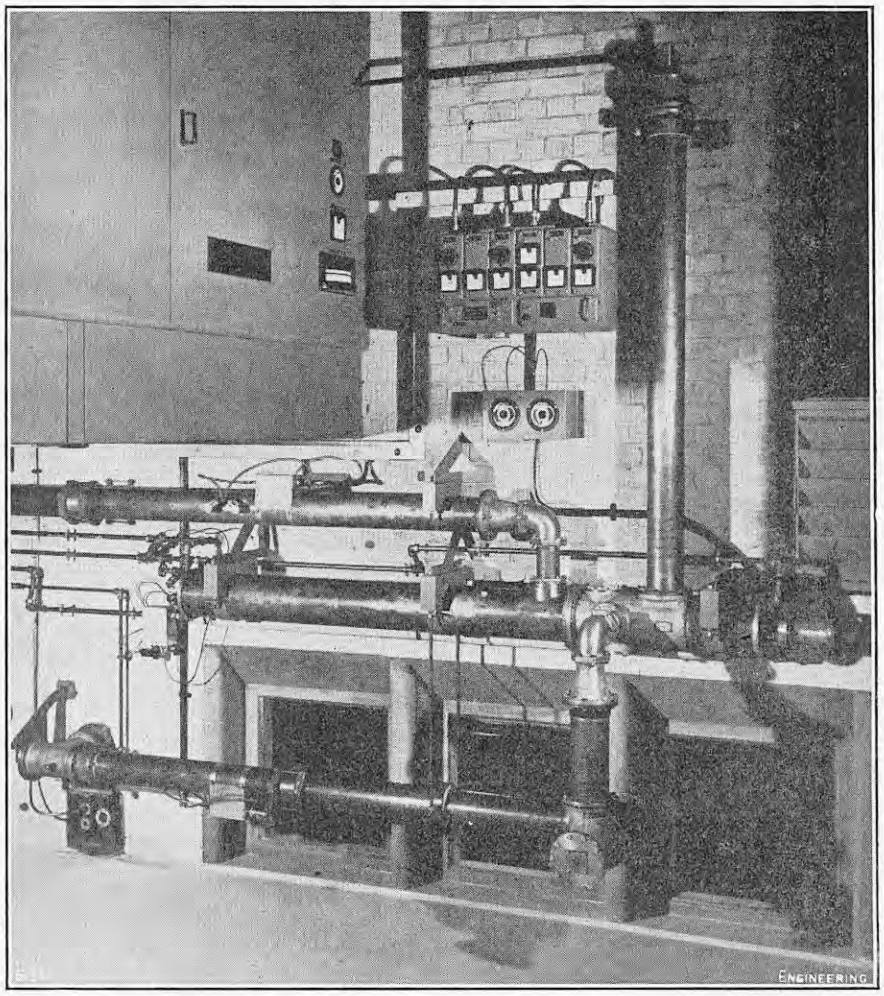


Fig. 3. Combining Unit.

dry air is blown into it. At the top of the mast the feeder terminates in a T-junction, one leg of which is connected directly to an unbalance-to-balance transformer, while the other is connected to a similar transformer through an extra quarter wavelength of line. The output of this second transformer therefore lags 90 deg. behind that of the first. The vision and sound signals are radiated from a single array, consisting of eight vertical folded dipoles. These dipoles are arranged in two identical groups placed one above the other and separated by a distance of about one wavelength. Each of the four dipoles in a group is mounted on one face of the square section top mast, those on the opposite faces being about two-fifths of a wavelength apart. They are constructed of galvanised steel strip and incorporate $7\frac{1}{2}$ kW heaters to prevent the formation of ice. The connections between the unbalance-to-balance transformers and the aerial are arranged so that the dipoles in both tiers are phased at 0, 90, 180 and 270 deg., a method which not only increases the power gain of the aerial, but results in a more constant input frequency over the frequency band. The standing wave ratio at the output of the combining unit is 0·96 to 1.

The main mast, which carries this aerial system, was constructed by British Insulated Callender's Construction Company, Limited, Bloomsbury-street, London, W.C.1. It is 750 ft. high and weighs 140 tons, and its design is generally similar to that at Sutton Coldfield, which has already been described in Engineering.* Up to the 610-ft. level, the cross-section is triangular, each face being 7 ft. across. Between the 610-ft. and 710-ft. levels the cross-section is circular, while the uppermost portion consists of a structure of square section. The circular portion of the mast is provided with eight tiers of four slots, so as to form an aerial for very high-frequency sound broadcasting should this system be adopted in future. A view of the upper portion of the mast is given in Fig. 1. In addition, there is a separate 150-ft. mast carrying emergency sound and vision aerials, for use if the main aerial or feeder system breaks down. These auxiliary aerials are supplied through coaxial cables manufactured by Telegraph Construction and Maintenance Company, Limited, Old Broad-street, London, E.C.2, details of which were given on page 235, *ante*. The maximum power on the auxiliary aerial will be 20 kW for vision and 5 kW for sound. Switches are provided so that a rapid change-over can be made from the main to the emergency systems. Stand-by transmitters with outputs of 2 kW for sound and 5 kW for vision are also provided and can be connected in emergency to either the main or reserve aerials.

Fig. 4. Control Desk.

As regards operation, the vision signals from Alexandra Palace will be transmitted via London and Manchester over coaxial cables, manufactured by Standard Telephones and Cables, Limited, Aldwych, London, W.C.2, and will be demodulated by Post Office equipment in a fully-screened termination room before being passed to the station control room and thence to the transmitter. A separate room contains the sound lines termination and test equipment, and the re-broadcast receivers. There is also a vision receiver, which is supplied from an aerial mounted at the 600-ft. level of the main mast and is directed at Sutton Coldfield. This aerial will, however, only be used in the event of a breakdown of the cable link, although tests have shown that pictures received in this way are of good quality and free from fading.

Both the vision and sound transmitters described above are operated from a single desk in the control room, an illustration of which is given in Fig. 4, and

* *Loc. cit.*

HOLME MOSS TELEVISION STATION.

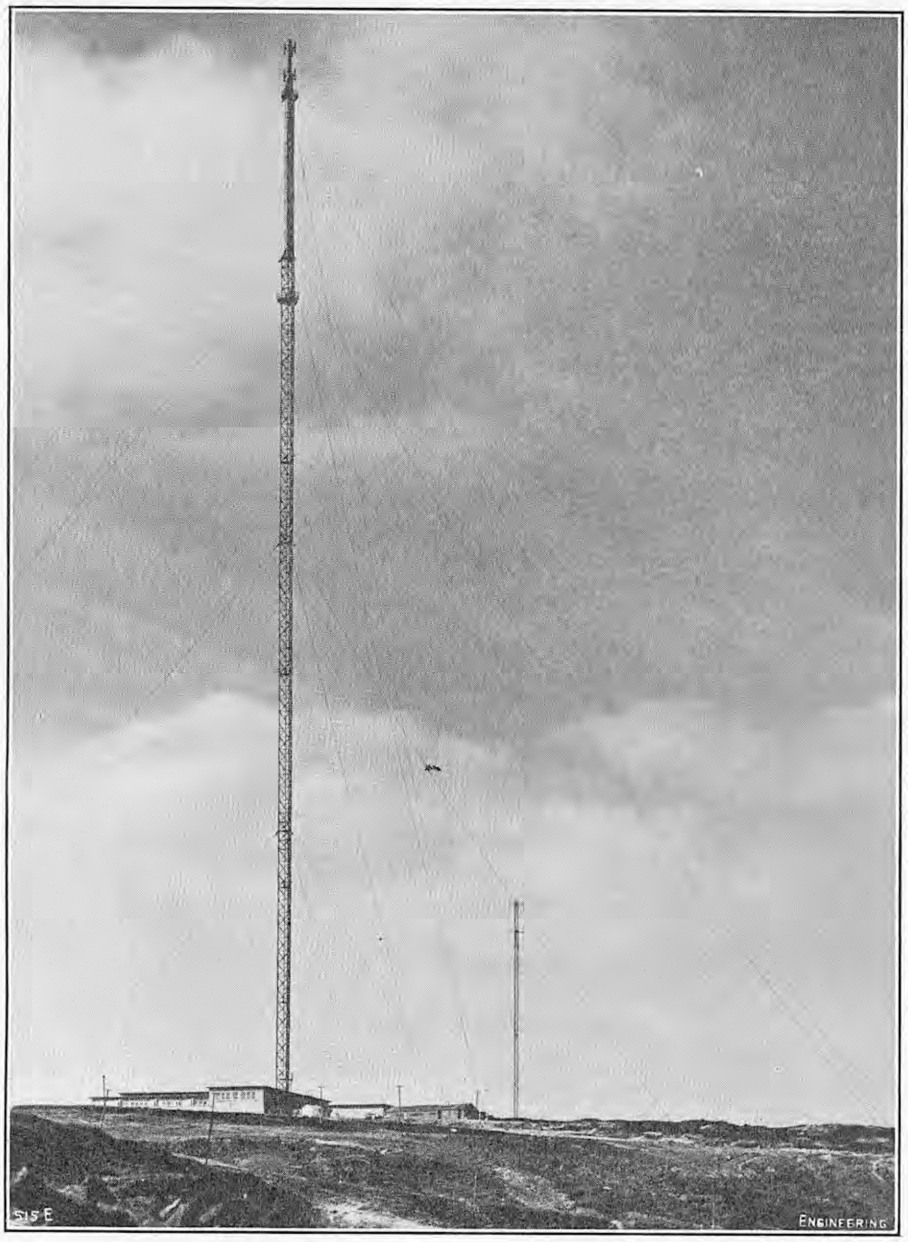


Fig. 5. View of Station and Masts.

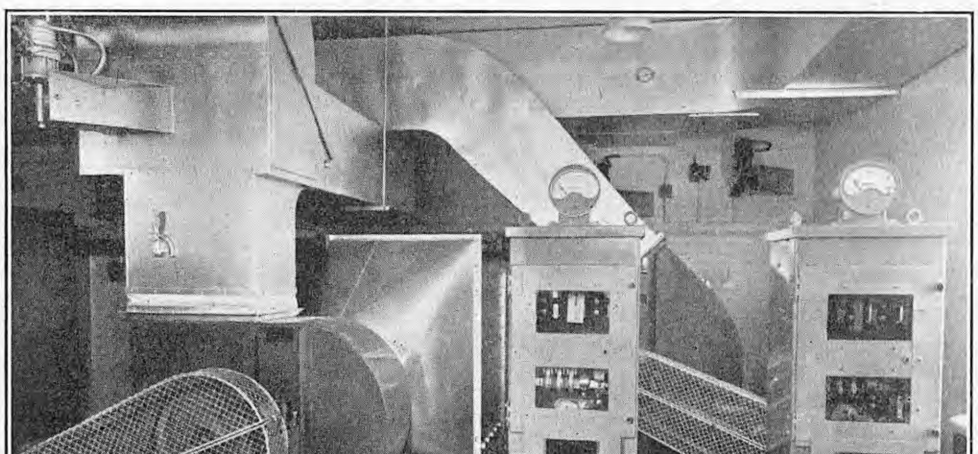


Fig. 6. Cooler Room for Vision Transmitter.

from which a clear view of both transmitters can be obtained through windows. The control systems employed are of conventional design and are operated by toggle switches. Sequence interlocking is used, the correct functioning of which is indicated by lamps on wall panels. Meters on the desk indicate the voltage of the various power supplies and the anode currents of the more important valves in the transmitter. The centre section of the desk houses a wave-form monitor, which can be employed to examine the output at various points in the modulator chain and on the outgoing radio-frequency feeder. Switches, which select the input signal fed to the transmitters, are also mounted on this section of the desk and enable either line signals or locally generated signals to be radiated. The latter normally consist either of test wave forms or of the output from one of a pair of monoscopes, which provide test card or apology captions as required. Pictures at the modulator output and as radiated, respectively, are displayed on two 12-in. monitors, which are mounted side by side in front of the desk and enable a direct comparison to be made. The quality of the vision and sound transmission can also be checked in a separate quality room, the walls, floor and ceiling of which have been acoustically treated and which contains a 15-in. picture monitor. This room can also be used as a studio.

Holme Moss will radiate the same programmes as the Alexandra Palace and Sutton Coldfield stations, and the vision signals will be transmitted from London via Birmingham and Manchester over coaxial cables operated by the Post Office. The vision signals which will be radiated from Holme Moss, will conform to the standards adopted for the British Television Service, i.e., 25 405-line pictures per second, each composed of two interlaced frames of 202½ lines. It has been found that the quality of the pictures is not impaired by the cable links, and an additional 11 million people should therefore be able to receive the programmes satisfactorily.

THE IRON AND STEEL INSTITUTE.

The autumn general meeting of the Iron and Steel Institute will be held on Wednesday and Thursday, November 21 and 22, at the offices of the Institute, 4, Grosvenor-gardens, London, S.W.1. The President, Mr. Richard Mather, will be in the chair.

On the first day, Wednesday, November 21, the proceedings will open at 10 a.m. After the transaction of formal business, there will be a joint discussion on two papers, namely, "The Crystal Structure of Graphite in Cast Irons," by Dr. W. S. Owen and Mr. B. G. Street, and "The Carbide Phase in Iron-Carbon-Silicon Alloys," by Dr. W. S. Owen. After a brief interval, two further papers will be presented at 11.45 a.m., and discussed jointly. They are "Metallography of Carbon in Silicon-Iron Alloys containing 4 per cent. Silicon," by Mr. E. D. Harry, and "The Variation in Electrical Properties of Silicon-Iron Transformer Sheet," by Mr. S. Rushton and Mr. D. R. G. Davies.

In the afternoon of November 21, the meeting will be resumed at 2.30, when there will be a discussion of a symposium of five papers on "Stresses in Moulds," and of two papers also dealing with the subject of moulds. These are: "Mechanical Properties of Ingot-Mould Irons," by Mr. J. W. Grant; "Poisson's Ratio for Cast Iron Used for Ingot Moulds," by Mr. J. Woolman; "Growth Characteristics of Some Cast Irons used for Ingot Moulds," by Mr. W. C. Heselwood and Mr. F. B. Pickering; "Note on Relaxation Tests on Cast Iron," by Mr. J. Woolman; and "Determination of Surface Stresses in Ingot Moulds," by Mr. M. W. Buttler and Mr. W. H. Glaisher. The two final papers are "Ingot Heat Conservation: Ingot Mould Temperature Measurements," by Dr. R. T. Fowler and Mr. J. Stringer, and "Ten-Ton Ingot Moulds: A Comparison of Design and Conditions of Use," by Mr. A. Jackson.

The first portion of the last session of the meeting, held on the morning of Thursday, November 22, and commencing at 10 a.m., will be devoted to the discussion of two papers, which will be taken together. They are: "The Production of High-Purity Iron and Iron Alloys on a 25-lb. Scale," by Mr. B. E. Hopkins, Mr. G. C. H. Jenkins, Mr. H. E. N. Stone and Mr. H. G. Short, and "Tensile and Impact Properties of Iron and Some Iron Alloys of High Purity," by Mr. W. P. Rees, Mr. B. E. Hopkins and Mr. H. R. Tipler. After a brief interval a paper by Dr. H. M. Finniston and Mr. T. D. Fearnehough, on "Physical and Mechanical Properties of Segregates in Two Alloy Steels," will be presented at 11.15 a.m. This will be followed at 12 noon by a joint discussion on two papers, namely: "Structural Transformations in the Tempering of High-Carbon Martensitic Steels," by Dr. K. H. Jack, and "Magnetic Analysis of Iron-Carbon Alloys: The Tempering of Martensite and Retained Austenite," by Mr. J. Crangle and Professor W. Sucksmith, F.R.S.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

End of Festival Ship's Tour.—The Festival of Britain ship Campania officially ended her tour of Britain at Glasgow on September 29. The total number of visitors who went on board during the two weeks the ship was moored at Springfield Quay was 92,559. She is expected to sail for Birkenhead shortly, where the exhibition will be dismantled.

City Development at Dundee.—Dundee Town Planning Committee were told on September 28 by Mr. W. Dobson Chapman, town-planning consultant, that his work was now so far advanced that it would be possible to present, some time in November, an outline plan on which the final city development could be based. The outline plan would show his recommendations for the principal lines of communication and for the location and readjustment of industrial, commercial, residential, civic, recreational, and open-space zones. In a progress report, he expressed the opinion that the population of Dundee was not likely to exceed 180,000 during the next 25 years.

Oil Refining in United Kingdom.—In so far as the Shell and Anglo-Iranian refineries in the United Kingdom are concerned, there need be no fear regarding their ability to keep running at full capacity in spite of the position which had arisen at Abadan, according to Mr. T. W. Lyle, general manager of Scottish Oils and Shell-Mex, Ltd. He was speaking in Falkirk, on September 28, at a dinner of the Scottish section of the Institute of Transport, following a visit to the new Grangemouth refinery of Scottish Oils, Ltd. The newly-extended refinery, with its accompanying pipeline across Scotland from Finnart, Mr. Lyle added, was the largest free-enterprise project undertaken by any company in Scotland since the end of the war.

Pumping at Bothwell Castle Colliery Shaft.—On October 5, Mr. P. J. Noel-Baker, Minister of Fuel and Power, granted an application by the National Coal Board for exemption from Section 36 of the Coal Mines Act, 1911, in respect of Bothwell Castle No. 1 shaft. This will permit the Board to continue to work this shaft for pumping purposes although there is at present only one outlet to the surface. The decision was against the advice given by the Chief Inspector of Mines that this course could not be recommended on safety grounds; but it was emphasised that, unless pumping continued, there would be no opportunity to determine whether the adjoining Priory Colliery, where the pumps were overwhelmed in April by an inflow of water, could be reopened for production.

Wagon Shortage and Exports of "Silt."—Owing to a shortage of wagons, a number of those being used in connection with the export of silt have been returned to ordinary pit work so that the tonnage of this inferior fuel, which has been making a substantial contribution to Scottish coal shipments overseas during the past few months, is now on a reduced scale. The demand for this fuel, a very considerable quantity of which remains in old washery ponds, remains firm.

Balloch Pier.—British Railways have announced that the existing wooden pier at Balloch, Loch Lomond, is to be demolished and replaced by a new structure of steel and concrete. Work on the project is expected to begin shortly, and it is hoped to complete the pier in time for the Easter sailings next year. P. Caulfield & Co., Bonhill, have been awarded the contract, which will involve about 15,000*l*.

Telford's Bridge over Clachan Sound.—A report to Argyll County Council on the state of the bridge over Clachan Sound, near Oban, which links the island of Seil with the mainland, states that, while the bridge is sound enough to carry the existing traffic, it will have to be replaced if the traffic becomes heavier. The bridge was built by Telford 160 years ago, and is known as "the bridge spanning the Atlantic."

Water Supply of Crail, Fife.—Police Judge D. Fraser, of St. Andrews, told Fife Water Supplies Committee on October 3 that, arising out of work for some Air Ministry projects in the Crail catchment area, the water supply for Crail had been polluted to such an extent that, on the instructions of the medical officer of health, the supply had been cut off. He added that Crail was at present being supplied from boreholes, which sufficed with the pumps going 24 hours a day, but would be inadequate in the summer months.

CLEVELAND AND THE NORTHERN COUNTIES.

Tees Exports and Imports.—Alderman B. O. Davies, presiding at the monthly meeting of the Tees Conservancy Commission, held on October 1 at Middlesbrough, drew attention to a report that tonnage exported from the Tees during August was the lowest recorded since August, 1949. He pointed out that the falling off in the quantities of scrap available, owing to the shortage of these materials, must have repercussions on exports of steel. In fact, the 105,379 tons exported in August were 28,000 tons below the figures for the corresponding month a year ago. On the other hand, imports of iron ore, recorded for the first eight months of this year, showed an increase over previous years. It is true that imports of iron and steel scrap continue on a very disappointing scale, but steel producers in Western Europe are sending rather better supplies of semi-finished steel for the Tees-side area. An improvement in the intake of steel semis is most welcome, as home-produced billets, slabs and sheet bars are in very short supply.

Haweswater Aqueduct, Westmorland.—On October 4, Sir William Kay, chairman of the Waterworks Committee of Manchester Corporation, detonated an explosive charge in the Fells near Kendal, Westmorland, to inaugurate the commencement of work on the twelve-mile northern section of the Haweswater aqueduct. The aqueduct will provide additional water in quantity for Manchester. It is stated that the northern section will be completed in three years at a cost of 2,000,000*l*.

Air Services in the North East.—On October 22, and 23, representative officers of the British European Airways Corporation are to visit the airport of Greatham, Stockton-on-Tees, and Woolsington, Northumberland, to survey existing air services and to hear evidence regarding the need for the introduction of air services to the Continent. The North-East Joint Airports Committee have interviewed industrialists and other local persons interested in the provision and extension of air services. One outcome of the visit may be to determine the future of the proposed airport at Boldon, Co. Durham.

LANCASHIRE AND SOUTH YORKSHIRE.

Trade Handicaps.—The new Master Cutler, Mr. Geoffrey Mainprize Flather, at his installation, on October 2, advocated the revision of import duties to protect, among other trades, Sheffield's cutlery industry. He instanced that during May, June and July over a million articles, such as pocket knives and scissors, which could have been made in Sheffield, had been imported from Germany. They were cheap because of the longer working hours and lower wages customary in Germany, and the fact that British import duties were still the same as in pre-war days.

Acquisition of Steel from the United States.—Mr. E. Senior, a former Master Cutler, is in the United States on a mission to acquire American steel to supplement home supplies. These are considered to be inadequate to meet commercial needs, and, at the same time, deal adequately with the rearmament programme. Mr. Senior is commercial director of the British Iron and Steel Federation and chairman of the Steel Rearmament Panel. Mr. W. E. A. Redfearn, President of the National Association of Drop Forgers and Stampers, and a special director of the English Steel Corporation, Sheffield, foreshadows that cuts will be made in the supplies to motor manufacturers from the drop forgers, except in the case of vehicles included in the rearmament programme.

Hadfields' New Forge.—The new forge shop at Hadfields Ltd., Sheffield, which constitutes part of a five-year plan announced three years ago as involving a cost of 4,000,000*l*., is to be formally opened on November 8 by the Duke of Gloucester. It houses, under one roof, two presses of 2,700 tons and 1,500 tons capacity, as well as furnaces and heat-treatment installations.

Short-Wave Warnings.—Supplies of short-wave equipment, to be used by Sheffield and Rotherham firms to receive early warning of power cuts, are scarce and the Yorkshire Electricity Board is concentrating supplies into the area because of the risk of spoiling costly steels in the process of manufacture and heat-treatment. It is emphasised that, in the Sheffield district, the steel industry needs more than the general warning which is to be sent out on the Light Programme of the B.B.C.

THE MIDLANDS.

Blast-Furnace Developments at Scunthorpe.—On September 26, No. 10 blast-furnace of the Appleby-Frodingham Steel Co., Scunthorpe, Lincolnshire, a branch of the United Steel Companies, Sheffield, was blown in after relining. Blowing-in was effected only 32½ days after the blast had been taken off the furnace. During this comparatively short time, a complete relining was carried out, the diameter of the hearth being increased from 22 ft. 6 in. to 25 ft. The auxiliary equipment was also overhauled and extensive modifications made to adjacent railway lines. At the Scunthorpe works, Redbourn, of Richard Thomas and Baldwins, Ltd., a new blast furnace has been blown in, which is expected to produce 500 tons a week. It replaces two old-type hand-charged furnaces. A new ore crusher having a capacity of 350 tons an hour has been brought into use, and the whole of the coke distribution system has also been modernised.

Birmingham's Development Plan.—The development plan for Birmingham, now before the City Council, has several features designed to overcome traffic problems. Particularly welcome to those who have to make business calls in the city will be the proposed extensions of car-parking facilities. There are plans for new car parks with a capacity of 7,400 vehicles, based on multi-storey and underground designs. New main roads proposed include three concentric ring roads, and tunnels, viaducts and fly-over crossings are planned in several places. The plan recommends that there shall be no extension of the city boundaries, and that the ultimate population shall be 1,081,000. To provide accommodation at a population density of 75 to 120 persons per acre in the inner zone, it is proposed to extend the use of flats and higher buildings generally.

Italian Labour in West Midland Pits.—Sixteen Italian mine-workers, having completed their training, are now employed in pits in the West Midlands. It was expected that the principal centre to have Italian labour would be North Staffordshire, and ten of the new mine-workers have gone there. Six, however, have started work at a pit in the Black Country—the Mobberley and Perry (Beech Tree) Colliery, near Lye, Stourbridge. Beech Tree pit employs about 230 men underground, and produces coal from the celebrated Thick Seam.

Discussion on Metal Supplies.—The National Union of Manufacturers (Midland Branch) is to call a meeting to discuss difficulties in obtaining priorities for materials used in sub-contracts which are themselves a part of a main contract having a priority symbol. Some Birmingham firms have reported that they cannot obtain materials, particularly copper and steel, to enable them to complete contracts in hand. One firm, the Midland Coil Winding Co., Ltd., Birmingham, are faced with closure of their works for lack of copper wire.

New Equipment at Wednesbury Steel Foundry.—An addition to the plant at the James Bridge Steelworks, Wednesbury, Staffordshire, of F. H. Lloyd & Co., Ltd., is a Beardsley and Piper (Chicago) "Speedslinger," the first of its type to be installed in this country. It is a hydraulically-controlled machine, travelling on rails of 4-ft. 8½-in. gauge, and is capable of ramming sand into moulds at a rate of 18 to 20 cub. ft. a minute.

SOUTH-WEST ENGLAND AND SOUTH WALES.

Coke-Oven Plant, Margam and Abbey Works.—When a party of engineers visited the new washery, coke ovens and by-products plant at the Margam and Abbey Works of the Steel Company of Wales, Ltd., at Port Talbot during the past week, they were told that the development of the works had meant an increase in the demand for furnace coke from 5,800 tons a week to 14,500 tons a week. To maintain this 12 railway lines have been laid down to bring in the 17,500 tons of coal needed each week. In 1940 there were 54 coke ovens at the plant but 90 more have since been added. A new washery that has been built can handle 500 tons more than the present capacity of the coke ovens.

Reconditioning of Armoured Cars at Llanishen.—The Llanishen Royal Ordnance Factory, Cardiff, has now become a depot for overhauling armoured cars and scout cars. Technical improvements have reduced the time required to bore gun barrels from 5 hours to 40 minutes. This has released more floor-space, which has enabled the reconditioning of armoured cars to be undertaken.

Need for Scrap in South Wales.—Captain H. Leighton Davies, at the annual meeting of the Welsh Tinplate and Sheet Trades Joint Industrial Council, at Swansea on October 5, complained that the local authorities were not co-operating as energetically as they might in the collection of scrap. He thanked Swansea for its initiative in the matter and expressed the hope that similar steps would be taken by local authorities from Newport to Llanelly, who had a special responsibility because of the dependence of those areas on the heavy industries. The old type of mills, said Captain Davies, had maintained output at the 1950 level. With the coming into operation of Trostre, he hoped they would continue in production for several years.

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.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Mersey and North Wales Centre:* Monday, October 15, 6.30 p.m., Liverpool Royal Institution, Colquitt-street, Liverpool. "Switchgear for Station Auxiliaries," by Mr. W. A. Snodgrass. *District Meeting:* Monday, October 15, 7 p.m., George Hotel, King-street, Reading. "The Relation Between American Universities and Industry," by Dr. P. Dunsheath. *Institution:* Tuesday, October 16, 6 p.m., Savoy-place, London, W.C.2. Discussion on "The *j* Operator Method of Calculation—When and How Should It Be Introduced?" opened by Mr. A. W. Gillies. *Southern Centre:* Wednesday, October 17, 6.30 p.m., Technical College, Brighton. "The Protection of Electrical Power Systems—A Critical Review of Present-Day Practice and Recent Progress," by Messrs. H. Leyburn and C. H. W. Lackey. *Scottish Centre:* Wednesday, October 17, 7 p.m., Heriot-Watt College, Edinburgh. Chairman's Address, by Mr. Percy Butler. *North Midland Centre:* Wednesday, October 17, 7.30 p.m., Yorkshire Electricity Board, Ferensway, Hull. Chairman's Address, by Dr. E. C. Walton. *East Midland Centre:* Thursday, October 18, 7 p.m., Corn Exchange, Spalding. "The Phase/Neutral System of Supply for Rural High-Voltage Distribution," by Messrs. G. T. Garwood and G. J. Websdale.

INSTITUTE OF METALS.—*Sheffield Local Section:* Monday, October 15, 7.30 p.m., The University, St. George's-square, Sheffield. Joint Meeting with the SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS. "Radioactive Tracers in Metallurgy," by Dr. H. M. Finniston. *General Meetings:* Wednesday, October 17, 10 a.m., Park-lane Hotel, Piccadilly, London, W.1. Discussion on "Metal Economics." Wednesday, October 17, 8 p.m., 4, Grosvenor-gardens, London, S.W.1. Conversazione and Exhibition. Thursday, October 18. Visits to works in London area.

INCORPORATED PLANT ENGINEERS.—*Dundee Branch:* Monday, October 15, 7.30 p.m., Mathers Hotel, Dundee. "Fuels and Firing Appliances," by Dr. E. G. Ritchie. *Glasgow Branch:* Tuesday, October 16, 7 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow. "Fuels and Firing Appliances," by Dr. E. G. Ritchie. *Edinburgh Branch:* Wednesday, October 17, 7 p.m., 25, Charlotte-square, Edinburgh. "Fuels and Firing Appliances," by Dr. E. G. Ritchie. *Western Branch:* Wednesday, October 17, 7.15 p.m., Grand Hotel, Bristol. "Ultrasonic Testing in Plant and Maintenance Engineering," by Mr. J. W. Fox. *Liverpool and North Wales Branch:* Thursday, October 18, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Factory Building Layout and Design," by Mr. J. W. Gray.

INSTITUTE OF FUEL.—Tuesday, October 16, 5.30 p.m., Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1. The Melchett Lecture, entitled "Combustion Processes in Engines," by Professor F. H. Garner. *Midland Section:* Tuesday, October 16, 6 p.m., James Watt Institute, Great Charles-street, Birmingham. Chairman's Address, by Mr. C. Machen. *North-Western Section:* Wednesday, October 17, 2 p.m., Engineer's Club, 17, Albert-square, Manchester. Joint meeting with NATIONAL SMOKE ABATEMENT SOCIETY. "Collection of Dust from Flue Gases," by Mr. J. C. Cleeves. *East Midland Section:* Thursday, October 18, 6.15 p.m., Gas Showrooms, Nottingham. Film Show.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Lancashire and Cheshire Branch:* Tuesday, October 16, 6.30 p.m., Engineer's Club, 17, Albert-square, Manchester. Chairman's Address, by Mr. R. M. Gray, and films of the New Tyne Bridge and the Ford Works, Dagenham. *Yorkshire Branch:* Wednesday, October 17, 6.30 p.m., Great Northern Hotel, Leeds. Chairman's Address, by Mr. A. Robb.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, October 16, 6.30 p.m., Lighting Service Bureau, 2, Savoy-hill, London, W.C.2. Presidential Address, by Mr. T. G. N. Haldane. *Coventry Branch:* Wednesday, October 17, 7.15 p.m., Coventry Technical College. Discussion on "Supervisory Remote Control Equipment." *Manchester Branch:* Wednesday, October 17, 7.30 p.m., Engineer's Club, 17, Albert-square, Manchester. "An Armchair Talk," by Mr. F. J. Pearce, *Crewe Branch:* Friday, October 19, 7.30 p.m., Copeland Arms Hotel, Glebe-street, Stoke-on-Trent. "Alternating-Current Motors and Control Gear," by Mr. F. T. Bartho.

INSTITUTION OF PRODUCTION ENGINEERS.—*Western Section:* Tuesday, October 16, 7.15 p.m., The Grand Hotel, Bristol. "Work Measurement and Results of Research Survey," by Mr. D. J. Desmond. *Birmingham Section:* Wednesday, October 17, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. "The History and Manufacture of Watches," by Mr. A. W. Marshall. *Coventry Section:* Wednesday, October 17, 7 p.m., Geisha Café, Hertford-street, Coventry. Joint Meeting with the INSTITUTE OF COST AND WORKS ACCOUNTANTS. "Factory and Plant Development Costs," by Mr. G. T. Verrall. *Edinburgh Section:* Wednesday, October 17, 7.30 p.m., North British Station Hotel, Edinburgh. "Some Aspects of a Factory Inspector's Work," by Miss G. M. Mitchell. *Glasgow Section:* Thursday, October 18, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. "Diamonds in Industry," by Mr. A. M. Livingston.

INSTITUTION OF WORKS MANAGERS.—*Leicester and Northampton Branches:* Tuesday, October 16, 7.30 p.m., Franklin's Gardens Hotel, Northampton. "Co-Partnership," by Mr. E. Scott-Bader. *Birmingham Branch:* Thursday, October 18, 7 p.m., Craven Arms Hotel, Coventry. Discussion on "The Foreman's Point of View; the Works Manager's Point of View," jointly with the INSTITUTE OF INDUSTRIAL SUPERVISORS. *West Yorkshire Branch:* Thursday, October 18, 7.30 p.m., George Hotel, Huddersfield. "Leadership in Industry," by Mr. J. Munro Fraser.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Midlands Centre:* Tuesday, October 16, 7.30 p.m., Crown Inn, Broad-street, Birmingham. "Plastics and Their Use in the Road Transport Industry," by Mr. L. A. White. *North-West Centre:* Wednesday, October 17, 7.30 p.m., Victoria Hotel, Wigan. "The Use of Light-weight Sandwich Materials in the Construction of Road Transport Vehicles," by Mr. F. C. Lynam. *London:* Thursday, October 18, 6.30 p.m., Small Assembly Hall, Central Hall, Westminster, S.W.1. "Brakes and Clutches," by Mr. Ivan M. Waller. *North-East Centre:* Thursday, October 18, 7.30 p.m., Hotel Metropole, Leeds. "Fleet Maintenance on a Large Scale," by Mr. W. R. T. Thomas. *South Wales Group:* Friday, October 19, 7 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "The Heating and Ventilation of Public-Service and Heavy-Goods Vehicles," by Mr. F. Duncombe.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, October 17, 5.30 p.m., Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1. The Presidential Address, on "The Inspecting Engineer's Contribution to Railway Economy," by Mr. Julian S. Tritton.

REINFORCED CONCRETE ASSOCIATION.—Wednesday, October 17, 6 p.m., Institution of Structural Engineers, 11, Upper Belgrave-street, London, S.W.1. "Moving Forms for Concrete Construction," by Mr. H. H. Broughton.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Yorkshire Branch:* Wednesday, October 17, 7.30 p.m., Royal Victoria Hotel, Sheffield. "Industrial Pipe-Work," by Mr. E. Ison. *Liverpool and District Branch:* Thursday, October 18, 6.30 p.m., N.W.G.B. Canteen, Kent-street, Liverpool. "High Pressure Hot Water in Industry," by Mr. J. R. Kell.

DIESEL ENGINE USERS ASSOCIATION.—Thursday, October 18, 2.30 p.m., Caxton Hall, London, S.W.1. "Test Methods for the Ignition Qualities of Diesel Fuels," by Mr. K. Arter.

INSTITUTION OF CIVIL ENGINEERS.—*Airport Engineering Division:* Thursday, October 18, 5.30 p.m., Great George-street, London, S.W.1. "Gravel Compaction and Testing, and Concrete-Mix Design at London Airport," by Mr. H. Smith.

ROYAL AERONAUTICAL SOCIETY.—Thursday, October 18, 6 p.m., Institution of Mechanical Engineers, Storey's Gate, London, S.W.1. "Modern Trends in Civil Airworthiness Requirements," by Mr. W. Tye.

SOCIETY OF CHEMICAL INDUSTRY.—*Road and Building Materials Group:* Thursday, October 18, 6 p.m., Institution of Structural Engineers, 11, Upper Belgrave-street, London, S.W.1. "The Durability of Tar and Tarmacadam," by Dr. A. R. Lee and Mr. E. J. Dickinson. *Corrosion Group:* Friday, October 19, 6.15 p.m., Chemical Society's Rooms, Burlington House, Piccadilly, London, W.1. General Meeting, followed at 6.30 p.m. by discussion on "Corrosion Problems in Industry," opened by Dr. W. H. J. Vernon.

INSTITUTION OF MECHANICAL ENGINEERS.—Thursday, October 18, 7 for 7.30 p.m., Dorchester Hotel, London, W.1. Annual Dinner. Friday, October 19, Storey's Gate, St. James's Park, London, S.W.1. 5.30 p.m. Presidential Address, by Mr. A. C. Hartley.

CHEMICAL SOCIETY.—Thursday, October 18, 7.30 p.m., Burlington House, Piccadilly, London, W.1. Tilden Lecture, entitled "The Contributions of Wave Mechanics to Chemistry," by Professor C. A. Coulson.

INSTITUTION OF CHEMICAL ENGINEERS.—*Midlands Branch:* Saturday, October 20, 3 p.m., Latin Theatre, The University, Edmund-street, Birmingham. "Recovery of Sulphur Dioxide from Effluents Obtained in Sulphuric Acid Manufacture," by Mr. L. Moller. *North-Western Branch:* Saturday, October 20, 3 p.m., Reynolds Hall, College of Technology, Manchester. "Chemical Engineering and the Future," by Sir Harold Hartley.

PERSONAL.

SIR CECIL WEIR, K.B.E., M.C., has joined the board of directors of the Pyrene Co., Ltd., Great West-road, Brentford, Middlesex.

MR. F. N. OWNER, C.B.E., M.Sc., M.I.Mech.E., F.R.Ae.S., joined the de Havilland Engine Co., Ltd., on October 1 as deputy chief engineer, immediately responsible to DR. E. S. MOULT, M.I.Mech.E., F.R.Ae.S., chief engineer of the company. MR. W. F. SHAYLOR was appointed commercial manager of the company on September 1.

MR. G. M. FLATHER has been installed as the 312th Master of the Company of Cutlers in Hallamshire, in succession to MR. WILTON LEE.

MR. STEPHEN FURNESS has relinquished his positions as chairman and a director of the Furness Shipbuilding Co., Ltd., Haverton Hill-on-Tees.

MR. N. ROWBOTHAM, C.B.E., Wh.Ex., F.R.Ae.S., M.I.Mech.E., M.I.P.E., has been obliged, for health reasons, to relinquish his appointment as divisional managing director, engine division, the Bristol Aeroplane Co., Ltd. He remains a director of the company.

SIR DONALD ST. CLAIR GAINER, G.B.E., K.C.M.G., will take up the appointment of chief executive of the International Road Federation (London office), 18, South-street, W.1, on October 15, after his retirement from the Foreign Office.

MR. WALTER D. BURNET, B.Eng. (Sheff.), M.I.Mech.E., a lecturer in mechanical engineering at the University of Sheffield since 1919, has retired. He will continue as a part-time lecturer until January, 1952.

MR. A. R. WRIGHT has been elected a director of Lansing Bagnall, Ltd., Kingsclere-road, Basingstoke, Hampshire.

MR. A. W. LEE, who has been a full-time member of the West Midlands Gas Board since its inception and was formerly general manager and secretary of the City of Birmingham Gas Department, has been appointed deputy chairman of the Board, in succession to MR. G. A. MATTHEWS. ALDERMAN G. E. HODGKINSON, of Coventry, has been appointed a part-time member of the Board.

MR. A. E. COOK, managing director of Cravens Railway Carriage and Wagon Co., Ltd., Darnall, Sheffield, 9, has retired from that position, but retains his seat on the board. His successor as managing director is MR. J. E. OWSTON.

MR. G. GORDON JACKSON, managing director of the Engineering Centre, Glasgow, since it was opened in 1947, has been appointed to succeed MR. H. M. MACINTYRE as Scottish Controller for the Ministry of Supply.

MR. C. A. COLPITTS, of Montreal, has been appointed assistant chief engineer, Canadian Pacific Railway. This post was formerly occupied by Mr. R. A. Emerson, who, as stated on page 431, *ante*, became chief engineer on October 1.

DR. J. W. MCDAVID, chairman of the Nobel Division of I.C.I. Ltd., has retired. He was first connected with the Ardeer Factory, Stevenston, Ayrshire, in 1912.

MR. G. D. F. PRINGLE, of Birmingham, has been elected President of the Engineer Surveyors' Association, 19, Atlantic Chambers, 7, Brazennose-street, Manchester, 2, for the year 1951-52. MR. F. S. BOWEN, of Manchester, has been appointed vice-president.

MR. A. C. NEWBY, formerly planning engineer, Charlton Works, has been appointed assistant works manager (tramways and trolleybuses) in the department of the chief mechanical engineer (road services), London Transport Executive.

MR. E. S. BOOTH, M.Eng., A.M.I.E.E., A.M.I.Mech.E., engineer-in-charge of the co-ordinating section of the generation construction department of the British Electricity Authority, has been appointed generation construction engineer of the Authority. MR. A. HOUGHTON BROWN, A.C.G.I., B.Sc., M.I.C.E., has been appointed senior civil engineer in the civil and building branch, chief engineer's department, of the Authority.

MR. G. B. WILLIAMSON, M.I.Mech.E., a director of Dunlop Cotton Mills, Ltd., Rochdale, has retired.

MR. R. F. NORRIS has relinquished his position with the oil-engine division of the Brush-A.B.O.E. Group to become general manager of D.M.M. (Machinery) Ltd., 119, Victoria-street, London, S.W.1.

MR. S. C. GREATRIX has terminated his connection with Roman Mosaic, Ltd., Tipton, to take over administrative control of Marbello & Durus, Ltd., and the Concrete Case Hardening Co., Ltd., Crescent Wharf, Birmingham, 1.

MR. W. B. ROBSON, A.M.I.E.E., has relinquished his position as head of the publicity and order departments of Brookhirst Switchgear Ltd., Chester, upon appointment as general manager, Cantie Switches, Ltd., Bromborough, Cheshire.

The telephone numbers of the Middlesbrough office of BRITISH INSULATED CALLENDER'S CABLES, LTD., are now Middlesbrough 2838 and 43569.

EXHIBITION OF MEASURING AND INSPECTION EQUIPMENT.

ALFRED HERBERT, LIMITED, COVENTRY.

FIG. 1. HILGER LATHE PROJECTOR.

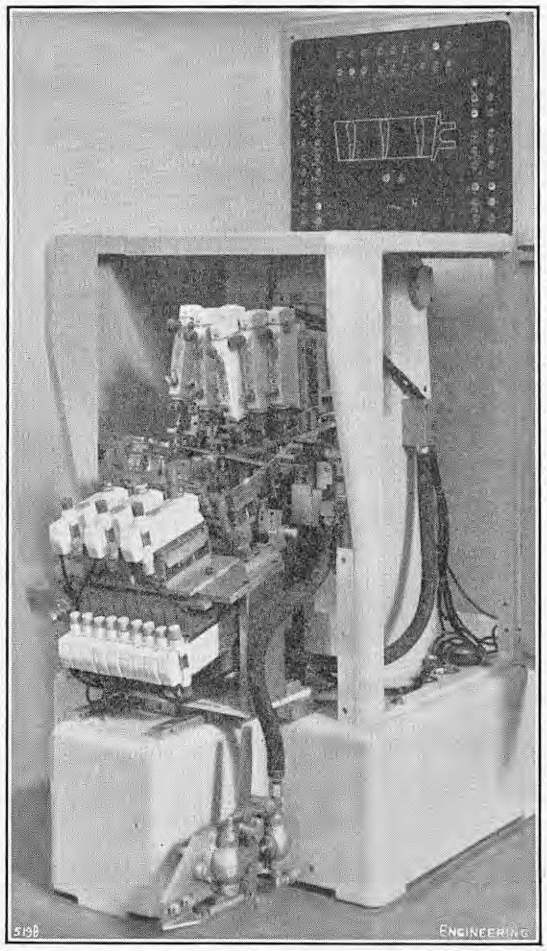


FIG. 2. SIGMA INSPECTION MACHINE.

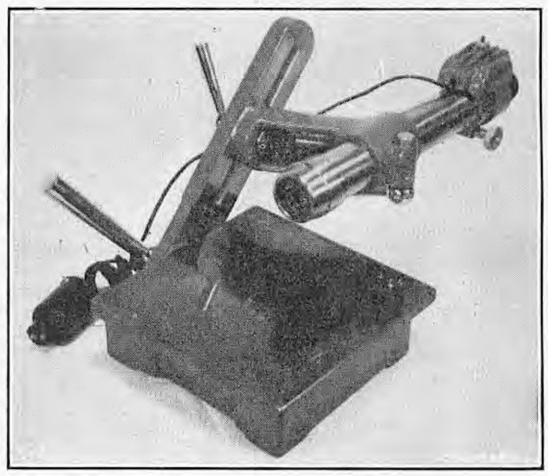


FIG. 3. HILGER ANGLE DEKKOR.

EXHIBITION OF MEASURING AND INSPECTION EQUIPMENT.

THE illustrations on this page show three examples from a wide range of measuring and inspection equipment on view at an exhibition at present being staged by Messrs. Alfred Herbert, Limited, Coventry, at their London office, 70, Vauxhall Bridge-road, S.W.1. The exhibition opened on Monday, October 8, and will remain open daily until October 19, including Saturday, October 13, from 10 a.m. to 5 p.m. Measurement in industry has become an exact science which is essential to efficient and economical manufacture, and there are many instances in engineering practice where equipment for measuring and inspecting is as important as the actual means for production. Messrs. Alfred Herbert, Limited, and the companies for which they are agents, are well known as manufacturers of high-precision machine tools and inspection and measuring instruments, and their standard products in the latter field are capable of meeting most requirements.

The lathe projector, illustrated in Fig. 1, is a compact bench projector for use with small lathes in the production of small components. In operation, the image of the component undergoing machining is projected on to a translucent screen at a magnification of 40 diameters. A drawing of the component on the same scale is mounted on the screen and reference lines enable the tool to be set to the correct diameter or length before taking the cut. The machining of small components is greatly simplified, as the lathe operator is able to observe the enlarged image of the workpiece while it is being cut to the appropriate contour. The projection screen is 7½ in. square and is provided with means for fine adjustment, so that the enlarged drawing may be set quickly and accurately in its correct position relative to the axis of the lathe spindle and the end of the material from which the component is being produced. The projection lens is designed to allow more than 1 in. clearance between the lens and the focal plane. The source of illumination is a 12-volt 48-watt filament lamp fitted in a lamp housing which is fully adjustable. After collimation, the light from the lamp is reflected upwards to the projection lens by a small mirror which can easily be removed for cleaning.

The high-speed inspection machine illustrated in Fig. 2 is representative of a large range of such machines manufactured by the Sigma Instrument Company, Limited, Letchworth, Hertfordshire, for whom Messrs. Alfred Herbert are the sole agents. These machines are made for hand operation, semi-automatic operation and fully-automatic operation, that illustrated being of the semi-automatic type. It is intended for checking components made in quantities not sufficiently large to warrant the use of a fully-automatic machine. The work under examination is loaded into the machine by hand and, on operating a foot control, banks of electric gauges close in to the measuring position, the gauges being actuated pneumatically. When inspection is completed, further operation of the foot control retracts the gauges and releases the component. Standard Sigma electric-signal gauges are used and these, it is claimed, give results within 0·00005 in. The panel includes plus and minus signal lights for each dimension, together with a further set of lights to show correct dimensions. Where the number of components warrants it, a fully-automatic type of machine is used. Generally this incorporates either hopper or magazine feeding for the components, which are automatically sorted according to their dimensions into separate containers.

The angle dekkor, illustrated in Fig. 3, is a precision optical device, the primary function of which is to check the angular relationship of plane surfaces. The instrument is made in three designs employing the same optical principle. There are two scales in the instrument, one being horizontal, fixed and permanently in the field of view, and the other vertical and visible only by reflection. A parallel beam of light, derived from a lamp and an optical system housed within the instrument, is projected on to the surface being checked. If this surface acts as a reflector and is in a plane approximately at right angles to the beam, the light is reflected back into the instrument and an image of the vertical scale is seen intersecting the horizontal scale. The position of the vertical scale relative to the horizontal scale indicates the error in squareness of the reflecting surface and the beam of light. The amount of the error can be read directly in minutes and estimated accurately to within ten seconds of arc. Other equipment on view at the exhibition includes an autocollimeter, optical dividing head, engineer's microscope, circular table, pitch-measuring machine, and various comparators, clinometers, levels, etc.

ENGINEERING,

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

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.

Telegraphic Address:
" ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to " ENGINEERING " Ltd. Cheques should be crossed " The National Provincial Bank, Limited, Charing Cross Branch." Post office Orders should be made payable at Bedford Street, Strand, W.C.2.

SUBSCRIPTIONS.

" ENGINEERING " may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance :—

For the United Kingdom and all places abroad, with the exception of Canada	£5 10 0
For Canada	£5 5 0

Subscriptions for periods less than twelve months are based on the price of a single copy, namely, 2*s*. 3*d*. post free.

CONTENTS.

ENGINEERING

FRIDAY, OCTOBER 12, 1951.

Vol. 172. No. 4472.

NATIONAL ELECTRICITY SUPPLY.

The third annual report* of the British Electricity Authority, which covers the year ended March 31, 1951, was published yesterday evening. Almost simultaneously, Sir John Hacking delivered his inaugural address as President of the Institution of Electrical Engineers. The former document gives an account of the operations of the Authority during a difficult period, an account which is mainly statistical in the broadest sense of the term, although there is also a good deal of technical information. In reviewing the more important developments in the fields of main generation and transmission, it was not surprising that Sir John Hacking covered much the same ground, although his review was more technical. In doing so, he also provided information about what is being done in other countries, against which British achievements over the past few years can be judged. In these two pronouncements, therefore, the electrical engineer has been provided with a fund of basic material which, for more than one reason, should be closely studied.

Dealing first with the Authority's report, it may be observed that a surplus of 6·33*l*. million was obtained on the year's working. This result, if satisfactory, is not spectacular; the previous year's surplus was 7·16*l*. million. In comparison, too, with a turnover of 237*l*. million it is distinctly modest. Of the revenue, nearly 97 per cent. was obtained from the sale of electricity and of the expenditure of nearly 231*l*. million over 45 per cent. was accounted for by the costs of generation and 24 per cent. by capital charges. The average price received was 1·181*d*. per kilowatt-hour sold, a figure which was 1·6 per cent. less than the average for 1949-50 and only 12·5 per cent. above that of 1938-39. The average price received per kilowatt-hour sold to domestic, commercial and small power consumers, who accounted for about half the total consumption, was, however, only 1·463*d*. per kilowatt-hour, compared with 1·515*d*. in 1949-50 and 1·596*d*. in 1938-39. The fact that in these difficult times any body, particularly a public corporation, should be selling at a lower price than before the war, is to be commended. The criticism may, however, be made that it is unwise to subsidise the domestic user at the expense of the power user; and the argument may be advanced that one way of cutting down the domestic consumption, as is advocated in some quarters, would be to put up the price, though we would not unreservedly support such a proposal.

In other circumstances, the expansion of the electricity-supply industry which is now taking place would be an occasion for congratulation. For instance, it is worthy of record that, at the date of the report, electricity was being supplied to over 13 million consumers, an increase of nearly half a million during the year and over three million more than before the war. These consumers purchased 46,500 million units, an increase of over 12·3 per cent on the 1949-50 figures and more than double the sales in 1938-39. Half these sales were to industry, a third for domestic purposes and one-eighth to commercial consumers. Farm consumption increased by 28 per cent., commercial usage by nearly 17 per cent., and both industrial and domestic consumption by 12 per cent. Some 9,930 farms were connected to the mains, bringing the total supplied on March 31, 1951, up to 109,962. If, as Sir John Hacking said, the first object of an electricity-supply industry is to supply electrical energy, it appears that the British Electricity Authority is not doing badly.

A further study of the report makes it clear, however, that this roseate picture must be toned down. On March 31, 1951, the installed capacity of the 289 power stations owned by the Authority was 14,592 MW and the total output capacity 13,156 MW. Of the former figure, 918 MW represented plant brought into service during the year. This was a greater increase than in any previous year, but the net advance was only 819 MW, owing to the shutting down of some unserviceable plant. Moreover, about 13 per cent. of the capacity was still represented by plant which was 25 or more years old. One result of this, as Sir John Hacking pointed out in his address, is that the average thermal efficiency of generation of a quarter of the total output in 1950-51 was as low as 16·23 per cent. If, on the other hand, it had been possible to commission all the new plant provided for in the programme for that year the overall efficiency would have been increased to 22·5 per cent. and about 1½ million tons of coal would have been saved. If, in addition, 1,000 MW of low-efficiency plant still in use had been replaced by new plant, this figure could have been increased to 23 per cent. and a further saving of some 800,000 tons of coal effected. It is hardly necessary to elaborate this point or to indicate the remedy.

The lag in the installation of generating plant behind the estimated figure has also had the effect of making it impossible to meet the peak-load demand during the winter months. This is shown by the fact that on December 18, 1950, the maximum potential demand* was 13,448 MW, of which only 11,229 MW could be supplied because 14 per cent. of the total output capacity was out of commission for one reason or another. This potential demand would have been greater but for load-spreading, restrictions on display lighting, and

* *British Electricity Authority. Third Report and Statement of Accounts for the Year Ended March* 31, 1951. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 8*s*. net.]

the response of the public to the demand for economy. Although this gap of 2,109 MW represented the maximum difference between demand and supply, there were, during the year, no fewer than 267 occasions where it was necessary to shed load, compared with 124 in 1949-50 and 79 in 1948-49. Moreover, this shedding occurred not only during the winter, but, owing to the necessity of overhauling the plant and the pressure of inclement weather, had to be enforced on no fewer than 90 occasions during the summer.

The remedy for this is the installation of more generating plant, and it is satisfactory to see that the Authority are well aware of this; for, although only three new power stations—Croydon B, Agecroft and Poole—with a present aggregate capacity of 260 MW were brought into operation during the year, at the date of the report 43 new stations and 31 extensions to existing stations were under construction or planned in the programmes for the period from 1951 to 1956. These stations will, of course, contain plant of the latest design and of increasing unit capacity, including straight condensing sets with individual outputs up to 60 MW at 3,000 r.p.m., each supplied from a single pulverised-fuel boiler. In fact, more than one-third of the total 13,000 MW which is in the coming five years programme will be arranged on the unit-boiler system. If everything had gone according to plan it should have been possible, therefore, to bring from 8,000 MW to 9,250 MW into commission between now and 1956, the lower figure being that which might, with confidence, have been expected to be available, and the higher that which it should have been possible to obtain if nothing untoward occurred.

Unfortunately, something untoward has occurred, for, since this forecast was made, the re-armament programme has been launched and the supply of raw materials has deteriorated. Even by the end of the year under review, there were indications that the manufacture of plant and the construction of buildings would be adversely affected. It seems, therefore, that it will be impossible to implement even the lower figure in the programme, unless power-station construction and equipment are given the highest priority. The anxiety of the Authority on this point is increased by the Government's proposal that the annual amount of generating plant for which finance will be allowed shall not exceed 1,500 MW, compared with the 1,800 MW which is required. As is rightly pointed out, this limitation would not merely prolong the conditions arising from plant shortage, such as load shedding; it would also hinder the greater mechanisation and extended use of power in industry, which are among the ways of improving efficiency. It must also be stressed that re-armament must result in an increased demand for electricity, so that, unless foresight is exercised, the position will become worse.

We have always been of opinion that the policy of the Government in the early part of the war, of refusing sanction to the generating plant programme of the Central Electricity Board, was mistaken. Indeed, we are sure that many of the subsequent troubles spring directly from it. It is to be hoped, therefore, that, whatever the complexion of the Government that is in office after October 25, they will realise that, without a plentiful supply of power, re-armament will be hamstrung, and that they will act accordingly.

The problem of providing an adequate supply of electricity for the nation's needs depends, however not only on the existence of sufficient generating plant, but on the availability of well-planned transmission and distribution systems. This, of course, is a matter for the Area Boards. At the present time, extensive reinforcement of the grid is becoming necessary to meet the rapidly-growing load and the same is true, probably to an even greater degree, of the various distribution systems. As regards the first, some relief may be expected from the new 275-kV scheme, on which work appears to be proceeding satisfactorily, but more than one of the Area Boards is expressing anxiety at the way in which restrictions upon capital development are retarding progress in the matters that come under their control. This, again, is a matter to which the closest attention should be given without delay. Finally, the consumer can play a part in these difficult times by exercising the greatest economy in consumption and by improving the efficiency of the processes he employs so that the strain upon generating capacity and upon fuel resources may be lessened.

* "Potential demand" is defined as the demand by the power stations, plus the estimated amount of load reduction due to low frequency and to load shedding by voltage reduction and disconnection of supply.

STEEL-FOUNDRY PROBLEMS AND ACHIEVEMENTS.

Since the Socialist party took over the government of this country in 1945, their worst enemies have often been some of the trade unions who supported them at that time. Attempts to integrate a nationalised industry and to introduce better methods have often been baulked by a stubborn refusal to accept the need for changes. The irony of this situation must bear particularly hard on the party leaders at the present time, the more so since it would not be in their interests to protest publicly. Unfortunately, it is generally not in anyone's interest to protest, and a discreet silence on the subject has therefore been maintained in the hope that those concerned would see the light and amend their ways before it was too late.

The silence has been broken this week by Mr. F. W. Rowe, chairman of the British Steel Founders' Association, who has accused the Amalgamated Union of Foundry Workers of not co-operating fully in the drive to increase productivity. "We find it extremely difficult," he said, "to get anything like full co-operation on this vital question of production from that union. They don't consider productivity as being a number one subject. They consider a lot of questions as being of equal or greater importance." On the other hand, Mr. Rowe said that the attitude of the workpeople towards increased productivity had improved; which suggests that the tactics of the union leaders do not accord with the feeling of the rank and file. Two points stressed by Mr. Rowe were that they had had some difficulty about the entry of older people into the industry, and that most craft unions took the view that unless a man had been fortunate enough to spend the years from 15 to 21 in an industry he should not join that trade. He said, of course, that the association were entirely in favour of the apprenticeship system, but they did not think it should be carried to such an extent that if a man had had no occupation in an industry until after he finished his military service he should be condemned to be a labourer for the rest of his life. Rigid rules relating to apprenticeship and the practising of a craft are not compatible with full employment, a progressive industry and a rising standard of living—nor, indeed, with re-armament—and if they are not relaxed something must suffer.

Mr. Rowe was speaking at a Press conference which the association had convened to present a report on the progress that has been made in the steel foundry industry since its productivity team, the first to visit the United States, published its report two years ago. The B.S.F.A. have gathered information from their member firms for this purpose, and the latest report shows the value of the inquiry and discussion which all the productivity teams generally have encouraged. Working conditions have been improved and amenities increased; training schemes have been introduced for apprentices, older entrants and supervisory staff; and productivity statistics and shop achievements have been publicised on the shop floor. Nevertheless, it is recognised in the report that these measures, welcome though they are, will not lead to greater productivity unless it is realised throughout the foundry that employers and employees have a common interest—the success of the firm. "No member," it is stated, "would claim to have the confidence of all his workpeople, and one or two wrongly blame their workers or their workers' trade-union leaders for their failure to obtain it; but blaming the other side will not help—good leadership is the only way to a good spirit throughout a concern."

As a result of the 1949 report, attention has been paid in many foundries to the improvement of layouts; a few have installed a new melting shop or new bays and others have extended their mechanised moulding, by the use of either moulding machines or sand-slingers. The efficiency and working conditions of fettling shops have also been improved. A certain jobbing founder has modernised the layout of his casting areas so as to accelerate the turn-round of boxes and reduce sand movement. Pattern shops have been reorganised and production control improved. In one foundry the movement of castings has been reduced by centralising the heat-treatment, burning-off and shot-blasting processes. These simple principles have long been known, as the report states, but it took the productivity team report to stimulate interest and action.

Nearly all founders mention the installation of new equipment or the better use of existing plant during the past three years, even in cases where they had already carried out extensive schemes of improvement and modernisation. Often, where equipment was already considered satisfactory, it was found possible to increase productivity. In one foundry, for example, the improvement, measured in man-hours per ton, has amounted to 14 per cent. on a sand-slinger, 47 per cent. on machine moulding, and 50 per cent. on fettling. Nevertheless, a considerable amount of new equipment has been brought in to the steel foundries; one firm has changed from open-hearth furnaces to electric-arc furnaces, though the shortage of electric power has apparently prevented a similar change in other foundries. Several reports from members reveal large increases in the productivity of moulding and fettling shops, and one founder has doubled his production since he introduced machine moulding.

Wider use is being made of mechanical knock-outs, flame-cutting machines, airless shot-blasting machines, and crane magnets, and the dust problem has been tackled afresh. In one foundry, a mechanical excavator has been brought in to dig the pits, and in others new sand-mixing equipment has been provided. The advantages of carefully-planned materials-handling equipment are now more generally appreciated, and even in jobbing foundries it has been found practicable to apply such methods and to standardise the sizes of moulding boxes. The scarcity of scrap has prevented a general turnover from basic to acid melting, though two foundries report that they have done so.

The cumulative effect of these improvements must be to give greater satisfaction to the industry's customers and thereby to enhance the prosperity of all concerned. The idea of sending productivity teams to the United States, when it was mooted, touched the pride of many industrialists, but some, such as the B.S.F.A. members, pocketed their pride. From a purely technical point of view they may have learned little, but they have been stimulated to self-examination and criticism. Other countries might follow this lead with advantage.

NOTES.

THE PARIS MOTOR SHOW.

THE 38th annual Salon de l'Automobile, which opened in Paris on Thursday, October 4, and closes on the evening of Sunday, October 14, is somewhat different from the London Motor Show, staged each year by the Society of Motor Manufacturers and Traders at Earl's Court, as it embraces almost all forms of road transport from the largest commercial vehicles down to the humble bicycle; trolley 'buses are also included. Moreover, the Paris Show is not held under one roof but, in two separate places, namely, the Grand Palais, Champs-Elysées, and the Parc des Expositions, Porte de Versailles. The cars and components, garage equipment, etc., are shown at the Grand Palais and the commercial vehicles, bicycles, motor cycles, etc., at the Parc des Expositions, where three of the larger buildings are in use, two being set aside for commercial vehicles, and the remaining one for bicycles, motor cycles, and associated equipment. Not all the commercial vehicles are being shown at the Parc des Expositions; some are being exhibited at the Grand Palais, so that a visitor interested in these alone has to visit both places. The effect of this seemingly haphazard dispersal on anyone whose interests embrace all sections is decidedly wearying. There is much to be said for the British practice of holding separate exhibitions, annually for motor cars and biennially for commercial vehicles and cycles. The motor-car section of the Paris Show undoubtedly is the most popular and in many instances it was difficult to obtain a clear view of the exhibits. In recent years, the French motor industry has undergone what amounts to a transformation, production and quality having risen steadily. Generally speaking, the Salon reflects this trend, there being a wide variety of cars on view, ranging from miniature two-seat vehicles fitted with engines as small as 125 c.c., to large luxury models such as the $4\frac{1}{2}$-litre Talbot. Some of the miniature cars provide transport and no more, there being the minimum of comfort and, in some cases, no weather protection worth mentioning. Others, such as the Renault and Panhard, are perfect examples of miniature cars which, on a reduced scale, include all the refinements of a modern medium-sized car. The exhibits, however, are by no means confined to French manufacturers; Great Britain, the United States, Italy and Germany are well represented. In general, there are no startling innovations and most of the cars on view, with the possible exception of some of the smallest, follow accepted principles of design. The same can be said of the exhibits in the commercial vehicle section, where a very wide selection of vehicles ranging from the heaviest articulated lorries to three-wheel delivery vans is being shown. Most of the heavy vehicles are fitted with compression-ignition oil engines which, in the majority of cases, are arranged for normal control. This, of course, does not apply to the 'buses and coaches, which are designed in almost every case for forward control. The movement towards underfloor engines has not gone so far in France as in this country, but at least two manufacturers are showing coaches with the engines installed in the rear boot. On one of these vehicles the engine is arranged across the chassis and the drive is taken forward to the rear axle through bevel gearing; on another the engine is in line with the chassis, but installed in the horizontal position. Some of the heavy trailers are of particularly interesting design and at least one semi-trailer incorporates torsion-bar springing for the rear wheels, each of which is independently sprung. In the motor-cycle section, the emphasis is definitely on the lighter machines, most of the heavier types being shown by Great Britain, Italy and Germany. There is a large selection of what can best be termed motor scooters, all powered by small two-stroke engines. Some of these machines are most attractive. On many of them, the standard equipment includes a spare wheel. The number of bicycles on show is remarkable, and the first impression gained is of their vivid colouring. Design is of a high standard throughout, a notable feature being the universal adoption of caliper brakes on front and rear wheels; even the smallest children's bicycles are so fitted.

THE FUEL POSITION.

A conference, organised by the Combustion Engineering Association, was held at the Dorchester Hotel, London, W.1, on Tuesday and Wednesday, October 9 and 10, to consider ways and means of alleviating the existing fuel and power shortage in this country. At the opening meeting on Tuesday morning, an address was delivered by the Minister of Fuel and Power (the Rt. Hon. Philip Noel-Baker), who briefly reviewed the experiments which were being made in the employment of fuels other than those in use. These, he said included the gasification of coal, and the development of water, tidal and wind powers, and would, no doubt, result in some useful information being gained. Among the wider aspects of the problem they had to consider was whether fuel was being used in the right way. It had, for instance, been pointed out that to employ gas for street lighting was very wasteful, and that it had, in fact, led to restrictions on the use of this form of fuel for industrial purposes. A great deal had been heard about the consumer being given a free choice, but the correct choice was not always made. A modern solid-fuel stove was a great deal more efficient than either an electric or a gas fire. The electric fire was also the main cause of the difficulties at peak-load periods and it had therefore become necessary to reduce the production of this equipment. If he used modern apparatus, the householder would soon find that he could get more heat from less coal and use small coal in a way which was not possible at present. Dealing with the fuel-supply situation, Sir Hubert Houldsworth said he hoped it would not be long before the Coal Board could provide all the coal that was needed. It was, however, incumbent on the consumer not to waste it. In achieving the savings that were essential, no great contribution could be expected from the domestic consumer, although he agreed that the development of proper methods of space heating was essential. On the other hand, a considerable saving could be made in industry without any loss of production. The policy of cutting down coal exports had been suicidal, since it had led to shortages of ore and pit props, for which there was a considerable demand. In spite of this restriction, stocks of coal were decreasing alarmingly and at the same time the industrial consumption was increasing. The difference would not be made up by miners working on Saturdays and he could only repeat that some way must be found of cutting down the consumption without reducing efficiency.

THE CO-ORDINATION OF CARGO-HANDLING PRACTICE.

In our issue of February 9, 1951, we printed a letter from Mr. A. C. Hardy, B.Sc., proposing the formation of an International Cargo Handling Committee in the hope of reducing the time taken to "turn round" ships in port by expediting the loading and discharging of cargo. Mr. Hardy explained that the proposed committee "would be purely unofficial, though of prime importance, in the first instance to manufacturers of rapid cargo-handling gear." He added that "the basic idea" had originated in France. Since that letter appeared, various preliminary meetings have been held of those interested in the project, and we are now informed by Mr. Hardy that an international meeting has been arranged for October 30, at which suggested Articles of Association are to be presented for discussion. The meeting will be held on board the Wellington, the headquarters ship of the Honourable Company of Master Mariners, which is moored off the Victoria Embankment, opposite the Temple, and the proceedings will begin at 10.0 a.m. It is proposed that, during 1951-52, the International Cargo Handling Co-ordination Committee (which is the title adopted) should undertake three preliminary tasks, namely, to classify all national organisations specialising in various aspects of cargo handling and to prepare a list showing the nature of their work; to classify all laboratories and exhibitions of cargo-handling equipment, with details of their potentialities, contents, and ability to supply information; and to classify all works, books and reports, dealing with cargo handling, which have been published since 1945. The membership of the committee, as proposed in the draft Articles of Association, would be limited to 125, comprising 15 founder members, 85 full members and 25 associate members, though it is provided in the draft Articles that the full total of 125 shall not be made up until after a meeting of the committee in June, 1953. Founder members might be either individuals (apparently representing only themselves) or nominees of associations or authorities; and it is hoped that the eventual composition of the committee will include a balanced representation of "shipbuilders, manufacturers of cargo-handling gear for use on board ship and ashore, port authorities, Chambers of Commerce, stevedores and dockers, packers, manufacturers of packing equipment, importers and exporters, [and] users of bulk cargoes (mineral)." Rather curiously, as it seems, shipowners are not specifically mentioned, though it will be appreciated that many of them are members of port authorities, Chambers of Commerce, etc., and would have ample opportunities to make their views known through these media. Broadly, it appears, "the aim of the association is exchange of information on cargo-handling technique, failures or mistakes made in various countries"; but the wording of the provisional Articles is rather vague in these respects. Possibly, the discussions at the meeting on October 30 may make them more definite. At present, some of the draft Articles seem better suited for inclusion in an explanatory memorandum than in a finalised legal document.

ROADS IN THE MIDLANDS AND SOUTH-WEST.

The British Road Federation have issued a pamphlet, entitled "The Midlands and the South West—New Roads," in which they stress the need to improve road communications between the Midlands, South Wales, and the Bristol area, on the lines proposed in the ten-year plan of the Minister of Transport, announced five years ago. These included a motorway, 76 miles long, from Birmingham to Almondsbury, north of Bristol; a bridge over the Severn between Aust, on the east bank, to Beachley, on the west; a motorway from Almondsbury, across the proposed bridge, and on to South Wales, by-passing Newport; a tributary motorway from Upton-upon-Severn, 17 miles north of Gloucester, to a point west of Ross-on-Wye; and modernisation of the roads crossing the heads of the Welsh valleys, to the South Wales ports, and from Cardiff to Merthyr, the by-passes at Port Talbot, Neath and Swansea; and the completion of the Cardiff by-pass. A map of the proposed new roads is printed on the back of the pamphlet. The total cost of these schemes is estimated to be about 35*l*. millions; but it is expected that, even on the basis of the present traffic, there would be an annual saving of 4*l*. millions in vehicle operating costs. It is expected, however, that there would be a considerable increase in the traffic if better road facilities were available; indeed, the traffic is increasing already, as more and more Midlands industries continue to establish branches in South Wales and to draw their raw materials from that region. At present, 97 per cent. of the country's entire tinplate production comes from South Wales, together with 54 per cent. of the coated and uncoated steel sheets and 30 per cent. of the cold-rolled strip. When the new steelworks at Port Talbot come into full production, of course, the production of steel in South Wales will be greatly expanded. Export trade from the South Wales ports, however, has decreased considerably, being only 10 million tons in 1949—less than half the 1938 total; this, of course, reflects the fall in coal exports. Improved roads, it is hoped, would encourage Midlands shippers to make more use of these ports and of Bristol, which are nearer than either Liverpool or London, and involve a shorter voyage to North America. An exhibition to illustrate these points, organised by the British Road Federation, has been on view during the past week at the showrooms of Messrs. Patrick Motors, Limited, Paradise-street, Birmingham. The brochure is obtainable from the Federation's office at 4a, Bloomsbury-square, London, W.C.1.

LETTERS TO THE EDITOR.

BRITISH ASSOCIATION DISCUSSION ON CONTRA-FLOW HEAT-EXCHANGE APPARATUS.

To the Editor of Engineering.

Sir,—Owing to the fact that I was away when your report of the discussion on my British Association paper on Contra-Flow Heat-Exchange Apparatus was published in your issue of August 24, 1951, I have only recently noticed that the report contained a number of inaccuracies, some of which were relatively unimportant. I should, however, be glad if you would publish corrections to those mentioned below, which are misleading.

Four lines from the end of the second paragraph in the middle column on page 244, "regenerator" should be inserted after "turbine"; and in the fourth line of the first paragraph in the right-hand column the word "adopted" should be replaced by "described." In the eighth line of the same paragraph the words "when using a" should be replaced by "as he used a third." Dr. Ezer Griffiths, whose remarks were reported in the second paragraph of the right-hand column, was referring to small-scale experiments and not full-scale experiments as printed; and in my reply to Mr. T. D. Patten in the third paragraph in the same column "decreased" should be read in place of "increased" in the eighth line from the end of the paragraph.

I appreciate the difficult conditions under which these meetings are reported, but I think you will agree that the above corrections should be put on record.

Yours faithfully,
For C. A. Parsons & Co., Ltd.,
C. E. Iliffe,
Applied Mechanics Research Engineer.
Heaton Works,
Newcastle-upon-Tyne, 6.
October 2, 1951.

TESTS ON CONCRETE WITH ELECTRICAL-RESISTANCE STRAIN GAUGES.

To the Editor of Engineering.

Sir,—I have read with considerable interest the article by Dr. N. S. J. Grassam and Dr. David Fisher on page 356 of your issue of September 21, as the work described therein is on the same lines as some carried out here, which has formed the subject of a paper submitted for publication. The method of attaching the gauges to concrete and the type of bridge used by Messrs. Grassam and Fisher appear to be essentially similar to those developed here.

The object of our work was to compare the strains recorded by electrical-resistance strain gauges with those obtained from Huggenberger tensometers. The strain gauges used were 200-ohm British Thermostat gauges of ½-in. nominal gauge length. The tests were carried out on a concrete cylinder 9 in. long by 4½ in. in diameter, the maximum size of the aggregate used being ¼ in. Four electrical-resistance strain gauges were mounted on each of two diametrically-opposite generators of the cylinder, as shown in Fig. 1. Bearing surfaces for the knife edges of the Huggenberger tensometers were provided by fixing small brass plates $\frac{1}{16}$-in. thick to the cylinder in the positions shown. These plates were attached to the concrete by the same fixing technique as that used for attaching the strain gauges. The loading faces of the cylinder were capped with plaster of Paris and rubbed down until they were smooth and normal to the longitudinal axis of the cylinder. Rubber sheets were not placed between the loading platens and the ends of the cylinder as was done by Messrs. Grassam and Fisher.

The cylinder was loaded in compression, and nine cycles of loading were carried out before readings were taken in order to minimise the effects of hysteresis in the electrical-resistance gauges. Thereafter, the electrical-resistance gauges were read at each increment of load up to a maximum of about 70 per cent. of the ultimate load of similar cylinders. Readings were taken while the load was reduced to zero by similar stages. During these tests the Huggenberger tensometers were mounted on the brass plates to obtain comparative readings of strain.

The strain distribution, over a longitudinal strip of the cylinder, obtained from the readings of the electrical-resistance gauges is shown in Fig. 2. A similar type of strain distribution has been obtained from the readings of the Huggenberger tensometers and also on the opposite longitudinal strip of the cylinder. Tests carried out on concrete cubes showed that the strain at the centre of a face was a minimum

Fig. 1

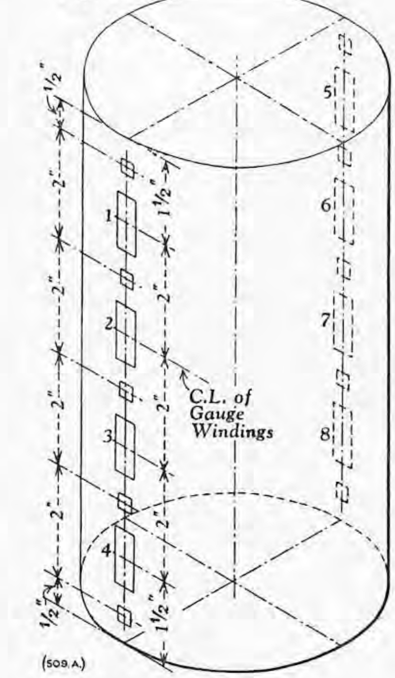
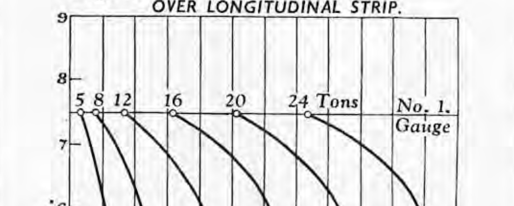


Fig. 2. STRAIN VARIATION OVER LONGITUDINAL STRIP.



and that it increased towards both edges. This type of strain distribution for a cube face has been mentioned by Binns and Mygind in the *Magazine of Concrete Research*, No. 1, January, 1949.

Since the Huggenberger tensometers measured the strain over a 2-in. gauge length it was necessary to apply a correction, which was obtained from the strain-distribution curves, to the tensometer readings before they could be compared with those obtained from the electrical-resistance gauges, the gauge length of which was ½ in. The strains recorded by the electrical-resistance gauges were calculated using the sensitivity factor given by the gauge manufacturers, and these were found to agree usually within 5 per cent. of the corrected strains as recorded by the Huggenberger tensometers, although differences of 10 per cent. were obtained.

It may well be that the sheets of soft rubber which Messrs. Grassam and Fisher used between the ends of the cylinder and the loading platens reduced the effects of end constraint to such an extent that the variation of strain was negligible. However, in view of the nature of the strain distribution along a generator, as shown in Fig. 2, I feel that some further experimental verification is necessary before it can be assumed that the rubber sheets eliminate the effects of end constraint, thus producing uniform compressive strain. I should be glad to know if the authors have any further information which they can give on this point.

In their conclusions, the authors state that when these gauges are used on concrete "they will have a strain-sensitivity factor which is about the same as that obtained on steel specimens." This would seem to imply that these gauges would have to be calibrated for each application on concrete. This procedure would not always be possible, and it seems more desirable to determine the reliability of the strains, as recorded by electrical-resistance strain gauges on concrete, on a basis of the manufacturers quoted sensitivity factor—especially since the sensitivity factor is virtually a function of the gauge rather than of the material to which it is attached.

Yours faithfully,
K. R. Peattie,
Lecturer in Civil Engineering.
The University of Nottingham.
September 29, 1951.

THE LATE MR. FRED CLEMENTS.

To the Editor of Engineering.

Sir,—I observe in your issue of September 28, on page 403, *ante*, it is stated in the obituary of the late Mr. Fred Clements that he was Master Cutler in 1939-40.

Mr. Clements was a Freeman of the Cutlers' Company, but he was never Master Cutler. The Master Cutler in 1939 was Mr. Ashley S. Ward, the then managing director of Thos. W. Ward, Limited.

Yours faithfully,
J. H. Whitham,
Secretary,
The Company of Cutlers
in Hallamshire.
Cutlers' Hall,
Sheffield, 1.
October 5, 1951.

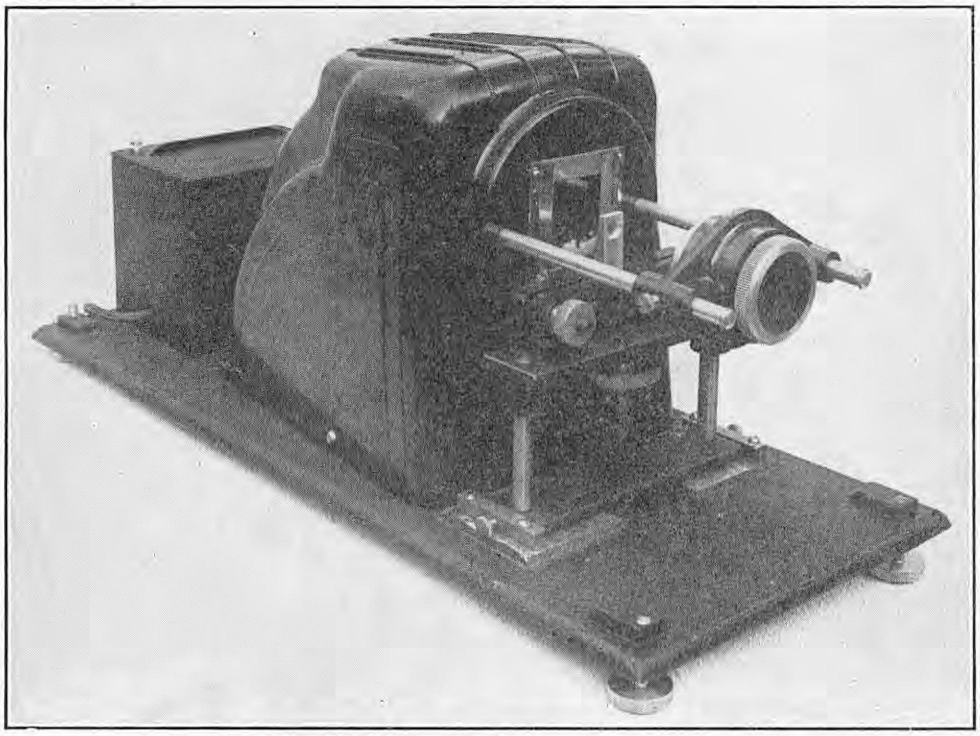
[We apologise for this error, which was due to a mis-reading of the notes in our file on Mr. Clements, and thank Mr. Whitham and others who have drawn our attention to it.—Ed., E.]

Gunboats for Peru.—We learn from Messrs. J. I. Thornycroft and Company, Limited, that the two shallow-draught gunboats Ucayali and Marañon, built for the Peruvian Navy at their Woolston shipyard, Southampton, have arrived at Iquitos, on the upper Amazon. These vessels, which are 155 ft. long and are driven by British Polar Diesel engines, made the voyage of 4,000 miles from Southampton to Parà and 2,000 miles thence up the Amazon, in 44 days. The 600-ton floating dock which Messrs. Thornycroft also built for the Peruvian Navy was towed from Southampton by the United Towing Company, Limited, Hull, and has arrived at Parà, on the way to Iquitos.

The Late Mr. C. T. S. Arnett, O.B.E.—We regret to record the death, on October 3, of Mr. C. T. S. Arnett, B.Sc., M.I.E.E., M.Inst.F., who had retired only a few days previously from the position of Controller of the North Western Division of the British Electricity Authority. Mr. Arnett, who was a graduate of the University of Durham, was apprenticed at the Heaton Works of C. A. Parsons and Company, Limited., Newcastle-on-Tyne, and afterwards joined the operating staff of the Cleveland and Durham Power Company. From 1913 to 1927, he was chief electrical engineer of Bolckow, Vaughan and Company, Middlesbrough, and then became chief engineer to Pease and Partners, Limited, Darlington. In 1931, he was appointed by the Central Electricity Board as operation engineer for the North-West England and North Wales Areas, succeeding to the position of manager in 1939. He became Controller of the North Western Division, B.E.A., in 1948, in which year also he was awarded the O.B.E. in the New Year Honours List.

OPTICAL PROJECTOR.

WATSON, MANASTY AND COMPANY, LIMITED, LONDON.



OPTICAL PROJECTOR FOR INSPECTION WORK.

It need hardly be mentioned that there are many occasions in engineering practice when an optical projector can perform a useful function. Not only in the tool room but also in the machine shop, projection can provide an inexpensive, convenient and rapid method of examining cutting tools, gauges and engineering components in general. By such means, also, parts may be examined during manufacture to determine whether errors caused by, say, faulty setting or blunting of the edge of a cutting tool, are present, and any necessary remedial action can at once be taken. In this way, wastage of materials may be eliminated and the work of inspection departments eased.

Although there are several examples of elaborate and expensive optical-projection equipment on the market which are suitable for high-precision work, there are, doubtless, many firms who would find simpler and cheaper, but nevertheless accurate, equipment of this kind of considerable general utility as well as sufficient for most of their needs. To meet such requirements, Messrs. Watson, Manasty and Company, Limited, 12, Clarges-street, London, W.1, have produced the apparatus shown in the accompanying illustration, which, though comparatively inexpensive, is capable of throwing a sharply-defined silhouette of an opaque object on a screen or wall at any magnification up to 50 diameters. Alternatively, the equipment can also be used to project film strip, Leica slides and microscope slides.

The apparatus, which is known as the W.M. Inspectoscope, employs a 12-volt 60-watt V-filament electric lamp, similar to a motor-car head-lamp, as its light source. The lamp is normally supplied from the mains, through a transformer having its primary winding tapped for 200, 220 and 240 volt inputs, but it may, of course, also be supplied direct from storage batteries. The transformer is contained in a box mounted on the baseplate behind the lamp-house. The latter also contains a concave reflector mounted behind the lamp, the light from which passes through an optical system consisting of two condensing lenses, which are ground and polished, and an objective which is a hard-coated anastigmatic lens of 3-in. focal length and aperture $f3$. The objective lens is mounted in a holder which slides on two guide rods fixed to a rotating head on the front of the lamp-house, the sliding motion being used for rough focusing. Subsequently, the lens holder is clamped in position by means of a milled screw, and a fine adjustment of the focus is made by rotating the lens, which is screwed into its holder.

A simple vice, which can accommodate specimens up to 1 in. in diameter, is mounted immediately in front of the lamp-house, between the condensing and objective lenses. The position of the specimen may be varied by means of a screw, which raises or lowers the jaws of the vice, or by sliding the whole vice fore or aft on its base. No lateral adjustment is provided. When slides are to be examined, they are held in a carrier which slips into a frame screwed to the rotating head. In this case, the vice may be removed entirely and the head may then be turned through 90 deg. if desired. Film-strip, similarly, is held in a gate-slide, also mounted in the frame referred to above. The diameter of the field of view is ½ in. and, as stated previously, magnifications up to 50 diameters are possible, although 25 diameters is the magnification recommended for normal practice.

The lamp-house, rotating head and lens mounting are in moulded plastic and the baseplate, which is fitted with four adjustable feet, is finished in black crackle enamel. The projector is provided with a wooden cover and, when boxed, measures 19½ in. by 9½ in. by 8 in. overall. The weight is approximately 20 lb. The numerous uses to which the equipment may be put include the examination of fine wire and gauze, needle points, threads, fibres and fibrous woven materials. Dimensions, curvatures, clearances, angles, etc., may be determined by actual measurement on the magnified image and, when appropriate, scaled down in the proper ratio. A datum piece, which is shown mounted in the vice in the illustration, is provided for determining the magnification. For serial testing, and in other special applications, the user would probably find it convenient to have a vice or holder made to suit the test-specimen. In such work also, an enlarged drawing of the part under examination may conveniently be mounted on the screen or wall and the silhouette projected upon it. Any departures of individual specimens from truth may then be observed directly. In conclusion, it may be mentioned that particular care has been taken over the design of the optical system of the Inspectoscope. The whole was carefully computed and the lamp has a special envelope, the glass of which is free from optical defects.

Building Research in Canada.—The first issue of a quarterly bulletin, *Building Research in Canada*, has been published by the Division of Building Research, National Research Council, Ottawa. The Division was formed in 1947 "to provide a research service to the construction industry of Canada." Investigations in progress or recently completed include a study of the transmission of vibrations from heavy traffic to buildings; the performance of a heat pump drawing heat from the ground; outdoor corrosion at various sites in Canada; the temperature of soil throughout the year; and condensation in buildings. The bulletin gives brief reports on these investigations, as well as articles on the Division, building research in Canada and other countries, publications of the Division, and the film library.

MAIN LONGITUDINAL STRESSES IN SHIPS.*

By J. M. Murray, M.B.E., B.Sc., M.I.N.A.

In this paper it is intended to survey briefly the development of the classical method of comparing the longitudinal strength of ships, and to suggest a simplification.

The study of investigations into the longitudinal strength of ships has now a history extending over quite a respectable period, for as early as 1746 Bouguer, in his *Traité du Navire*, calculated the bending moments on floating geometrical solids approximating in form to ships. Thereafter the matter received further attention, but the first systematic consideration of the bending moments imposed on a ship in service is found in *Shipbuilding, Theoretical and Practical*, by W. J. Macquorn Rankine, published in 1866. In this remarkable work, the following rule is given: "In ships of similar figures with weights similarly distributed, the greatest bending moments are proportional to the products of the displacements and lengths"; and, for ships of various geometric forms, having the weight of hull and cargo distributed over the length in an arbitrary manner, Rankine gives the bending moments in the still-water, hogging and sagging conditions in terms of the product of the displacement, the length and a factor. The question of relating these bending moments to specific ships, however, was left to William John, who, in his classic paper "On the Strength of Iron Ships"† considered the case of a ship 300 ft. in length, balanced on a wave the length of the ship and 12 ft. in height. In this paper appears the well-known expression, maximum hogging moment = displacement $\times \frac{\text{length}}{35}$; a formula for bending moment which has had a wide currency ever since. John made his calculations for a ship in the end-of-voyage condition, for which he estimated the constant to be 38; and concluded that, making allowance for higher waves and a less favourable distribution of cargo, the constant would reach the figure of 35.

In this study, which has influenced greatly subsequent ideas on the matter, the affect of the still-water bending moment was neglected, but 20 years later, in an important paper by Vivet,‡ the fundamental ideas enunciated by Rankine were again emphasised. Vivet remarked that the bending moment depends on two terms: "one is none other than the moment in still water; the second depends entirely on the movement of the centre of buoyancy under the influence of the wave." In this paper, the still-water and wave components of the bending moments of several ships are investigated and a formula is introduced to give the total bending moment. This formula can be expressed in a form in which the bending moment in still water and the bending moment due to the wave appear separately. In spite of the work of Vivet, which was followed by others, notably those of Alexander§ and Suyehiro,‖ the bending moment on a ship in a seaway was generally considered as a whole, until recently. The late Dr. J. Foster King, however, in two papers,¶ exerted his strong influence to direct the study of the subject back to fundamentals, and now there is again a disposition to examine the bending moment in its two components, that due to the still-water bending, and that due to the wave.

The author strongly supports this technique, and in a paper** suggested a method of calculation by which this could be done quickly. The usual method of balancing the ships on a wave and integrating the resultant load curve is tedious, and sometimes does not lead to particularly accurate results. As an alternative, it is sufficient to compute the bending moment in still water by means of the following formula: Let Mf = the moment of weight, and $M_1 f$ the moment of buoyancy, forward of amidship, and Ma and $M_1 a$, respectively, the moments of weight and buoyancy abaft amidship; then $Mf - M_1 f = Ma - M_1 a =$ B.M.

* Paper presented at the 2me. Congrès International des Ingénieurs Navals, organised by the Union Belge des Ingénieurs Navals and held in Ostend from July 19 to 22, 1951. Abridged.

† *Trans. I.N.A.*, vol. 15, page 74 (1874).

‡ "Etude sur la Fatigue des Navires," by L. Vivet. *Bull. Assoc. Technique Maritime*, 1894.

§ "The Influence of the Proportions and Forms of Ships upon their Longitudinal Bending Moments among Waves," by F. H. Alexander. *Trans. I.N.A.*, vol. 47, part 1, page 116 (1905).

‖ "A Method of Estimating the Maximum Bending Moments of Ships," by K. Suyehiro. *Jl. Soc. Nav. Arch., Japan* (1913).

¶ "Bending and Loading of Ships," *Trans. I.N.A.*, vol. 70, page 37 (1928); and "Longitudinal Bending Moments," *ibid.*, vol. 86, page 214 (1944).

** "Longitudinal Bending Moments." *Trans. I.E.S.S.*, vol. 90, page 365 (1946-47).

An approximation to the moment of buoyancy may be made by using the formula: mean bending moment = half displacement × mean longitudinal centre of buoyancy (L.C.B.) of fore-and-aft bodies $= \frac{D}{2} \times (0{\cdot}165\ C b + 0{\cdot}074)\ L$, where $C b$ = block coefficient.

The wave bending moment may be computed from the formula, W.B.M. $= b\ L^3\ B$, where L is the length, B the beam, and b is a coefficient depending on $C b$. Values for b are given in Table VIII, on page 472. It should be noted that these constants apply to the load draught of about 0·06 L; wide experience with these formulæ shows that, for ordinary forms, they are remarkably accurate. Designers can, of course, use constants derived from their own experience.

It is now proposed to examine the stresses on ships in some detail, in order to assess the importance of the two components, and to see whether the usual assumption can be justified, that the most suitable criterion of the strength of a ship is the stress induced when the ship is balanced on a wave of its own length. Since such a calculation—this must be emphasised—is only intended to give comparative results between ship and ship, the precise height of the wave used is not of fundamental importance, but obviously, the closer the assumed conditions are to actual conditions, the better. By custom, however, the height of the wave is taken as one-twentieth of its length, as this is thought to lead to results reasonably in accordance with service results. As a matter of interest, it may be noted that Vivet in his calculations, to which reference has been made, did not use a standard wave having a constant relation between height and length. He based his calculations on observations made by Lieut. Paris, and adopted a height which varied from one-twentieth of the length to one-thirtieth as the length was increased from 30 m. (100 ft.) to 185 m. (600 ft.).

Here, it should be emphasised that, whatever may be the stresses sustained through the influence of waves, there is no doubt that the stresses obtained from the still-water calculation approximate very closely to those sustained by the ships in that condition. The main result of the Newcombia and Neverita experiments* is that a ship behaves, for all intents and purposes, as a girder, and that the Euler-Bernouilli formula for calculating the stresses gives acceptable results. There are, of course, certain refinements which may be adopted, and which will help to reconcile theoretical and observed results, but they are not considered here.

For the purposes of this paper, it is intended to consider one family of ships, namely, single-screw Diesel-engined cargo ships of the shelter-deck type, having the lengths of 91·5 m. (300 ft.), 122 m. (400 ft.), and 137 m. (450 ft.). The dimensions and particulars are given in Tables I to IV, herewith.

The bending moments in still water have been computed on the assumption that half of the fuel has been burned out, a condition which it has been found is reasonably in accordance with average loading in a ship. The calculations have been made on the assumption that the holds are loaded with a homogeneous cargo. From the results (Table IV) two main conclusions may be drawn, namely, that the ships are subjected to a hogging moment, and that the bending moment is not greatly affected by altering the block coefficient from 0·75 to 0·70. The reduction in displacement is counterbalanced by the increase in distance between the centres of effort of the weight and buoyancy in the fore and after bodies. As may be seen from the calculation, this increase follows from the longer machinery space in the finer ship, so that the cargo is moved away from midships, and the centre of effort of the buoyancy moves towards amidships with reduction of block coefficient.

Next, the stress due to the hogging bending moment has been calculated, and here only the tensile stress at the deck is considered; the compressive stress on the bottom may result in some ships in deformation of the bottom plating, but it is not intended to consider that phenomenon here. The sectional modulus used is that derived from the load line formula $\frac{I}{y} = fBD$, where B = beam, D = draught, and f is a factor. The stresses are therefore as given in Table IVa.

TABLE I.—Particulars of Ships.

Length, Ft.	Beam, Ft.	Depth, Ft.	Draught, Ft.	Block Coeff.	Displacement, Tons.	Speed, Knots.	B.H.P.
300	45	27·6/ 20·6	20·1 20·0	0·70 0·75	5,470 5,800	12·0 10·5	1,900 1,400
400	55	36·33/ 27·83	25·1 24·9	0·70 0·75	11,200 11,900	14·0 12·0	4,650 3,250
450	60	41·0/ 32·0	27·8 27·6	0·70 0·75	15,200 16,100	15·0 13·0	7,100 5,000

Table II.—*Hull and Machinery Weights.*

Length, Ft.	Block Coeff.	Machinery Weight, Tons.	Length of Machinery, Space, Ft.	Hull Weight, Tons.	Light Ship, Tons.
300	0·70 0·75	400 350	42·0 40·0	1,480 4,500	1,880 1,850
400	0·70 0·75	720 560	53·0 48·0	2,770 2,800	3,490 3,360
450	0·70 0·75	1,000 750	57·0 54·0	3,850 3,900	4,850 4,650

TABLE III.—Oil Fuel Required.

Length, Ft.	Range, Miles.	Speed, Knots.	Time, Hours.	B.H.P.	Fuel, Tons.	Total Fuel, Tons.
300	6,000	12·0 10·5	500 570	1,900 1,400	180 150	200 170
400	8,000	14·0 12·0	570 670	4,650 3,250	500 400	550 440
450	10,000	15·0 13·0	670 770	7,100 5,000	890 720	980 790

TABLE IV.—Weight of Ship, Cargo and Fuel; and Still-Water Bending Moment.*

Length, Ft.	Block Coeff.	Light Ship, Tons.	Fuel, Tons.	Stores and Fresh Water, Tons.	Total. Tons.	Displacement, Tons.	Cargo, Tons.	Still-Water B.M., Ft.-Tons.
300	0·70 0·75	1,880 1,850	100 80	50 50	2,030 1,980	5,320 5,670	3,290 3,690	18,000 17,000
400	0·70 0·75	3,490 3,360	270 220	70 70	3,830 3,650	10,860 11,610	7,030 7,960	46,500 46,500
450	0·70 0·75	4,850 4,650	490 390	100 100	5,440 5,140	14,610 15,610	9,170 10,470	63,000 66,500

* Conditions with fuel half burned out.

Table IVa.

Length—						
m.	91·5		122		137	
ft.	300		400		450	
Section modulus—						
$cm.^3$ ..	12,400		30,400		44,500	
$m.^2$-ft. ..	6,300		15,450		22,600	
Block coeff. ..	0·70	0·75	0·70	0·75	0·70	0·75
Still-water B.M. (hogging)—						
Tonnes-m. ..	5,550	5,250	14,400	14,400	19,500	20,500
Tons-ft. ..	18,000	17,000	46,500	46,500	63,000	66,500
Corresponding Stress, kg. per sq. cm.	445	425	475	475	440	460
Tons per sq. in. ..	2·8	2·7	3·0	3·0	2·8	2·9

It is therefore apparent that, for this family of ships, the stress in still water, calculated on the above assumptions—which, it may be repeated, give a reasonable average of service results, does not vary greatly.

Having obtained the stress in still water, the stress due to the passage of the wave must be considered. First, the stresses were calculated on the assumption that the ships are placed on a standard wave having a length equal to the length of the ship, and having a height equal to one-twentieth of the length. For this purpose, the wave bending moments have been calculated from the formula:

$$\text{W.B.M. (Hogging)} = b\ L^3B \times 10^{-5}$$

where $b = 82{\cdot}5$ when $Cb = 0{\cdot}75$

and $b = 77{\cdot}0$ when $Cb = 0{\cdot}70$

This gives the following bending moments and stresses:

Length—						
m.	91·5		122		137	
ft.	300		400		450	
Block coeff. ..	0·70	0·75	0·70	0·75	0·70	0·75
Wave B.M. (hogging)—						
Tonnes-m. ..	8,100	8,700	23,600	25,200	36,200	39,000
Tons-ft. ..	26,000	28,000	75,000	82,000	116,000	126,000
Corresponding Stress, kg. per sq. cm.	650	700	775	825	815	870
Tons per sq. in. ..	4·10	4·45	4·90	5·25	5·15	5·5

In this calculation, the hogging moment alone was considered, since, when taken with the still-water moment in the loaded condition, with modern ships, it is the more important. It can also be established that the assumption of a wave the length of the ship represents the most severe conditions and this is shown in the appendix to the paper. For example, it may be argued that, if a ship 122 m. (400 ft.) in length meets waves 122 m. (400 ft.) long and 6·1 m. (20 ft.) high, the same wave will be met by the ship 91·5 m. (300 ft.) long and calculations should be made accordingly. As is shown in the appendix, the effect on the 91·5-m. (300-ft.) ship of a wave 122 m. by 6·1 m. (400 ft. by 20 ft.) is the same as that of one 91·5 m. by 4·6 m. (300 ft. by 15 ft.).

It is now useful to consider to what extent the waves of the sea during a storm conform with the theoretical trochoidal wave, and, what is more important, whether there is any correlation between the stresses calculated on the usual assumption, and those actually experienced in service.

Perhaps the principal characteristic of the ocean storm wave is its irregular form. Nevertheless, to study the motion of a ship in a seaway, it has been necessary to assume an idealised concept of a wave, and the use of the sinusoidal wave, or the trochoidal wave form, has made it possible to arrive at certain theoretical conclusions on the behaviour of ships. In some respects, too, these assumed wave surfaces correspond, to a reasonable extent, with the actual conditions; for instance, observations made on the pressure effects of ocean storm waves seem to demonstrate that the wave does, in effect, act in accordance with the trochoidal theory. So far, the most extensive observations reported on the configuration of ocean waves are those made during the experimental voyages of the San Francisco,* and the stereoscopic records taken on that occasion show clearly the confusion and lack of symmetry of storm waves. The records of the experimental voyages of the Ocean Vulcan are not available at the time of writing, but the wave profiles given in the preliminary report on these experiments† seem to confirm the previous findings; not only is the wave profile on the ship irregular, but it differs on the two sides of the ship.

Pommellet‡ contends that the ocean swell is formed of groups of waves along the direction of propagation. A heavy sea subjected to wind force is comprised of groups of waves, with a lateral length small in relation to the distance from trough to trough. The surface of the sea, in his opinion, can be considered to be constituted at any given moment of a series of waves of slightly variable direction, speed and length, the two

* "Structural Investigations in Still Water on the Welded Tanker Neverita," by R. B. Shepheard and J. Turnbull. *Trans. I.N.A.*, vol. 88, page 78 (1946); and "Structural Investigations in Still Water on the Tanker Newcombia," by the same authors. *Trans. N.E.C. Inst.*, vol. 63, page 237 (1947).

* "Beanspruchung des Schiffes im Seegang," by Dr. G. Schnadel. *Jahrbuch S.T.G.*, 1935.

† "The Measurement and Recording of the Forces Acting on a Ship at Sea," Part 1, by F. B. Bull and Professor J. F. Baker. *Trans. I.N.A.*, vol. 91, page 29 (1949).

‡ "Houle, Roulis, Tangage, Stabilisation," by A. Pommellet. *Bull. Assoc. Technique Maritime*, 1949.

last-mentioned characteristics being related. Photographs of storm waves in the papers of Pommellet and Dr. Schnadel confirm the absence of any specific regularity in ocean waves. Dr. Schnadel remarked that, in general, the largest waves mainly rolled up in groups of two, three or four, while smaller waves intervened. The appearance of such groups of larger waves was generally connected with a violent squall. Nevertheless, from time to time, there is interaction between groups of waves, so that, as is well known, the sea lessens or increases without alteration of the wind force. Occasionally, therefore, single waves of regular form are encountered. Dr. Schnadel instances a wave 186 m. long and 16·5 m. high having been encountered in the North Atlantic during a storm.

Enough has been said to indicate that waves are generally irregular, and here it may be mentioned that Pommellet is of the opinion that, contrary to the general belief, the irregularity persists in large oceans even when the conditions which produce swell have disappeared; superficial agitation, due mostly to the local effect of the wind, disappears, but the general configuration of the sea, seen on a large scale, does not seem to alter. It is held, however, that the theoretical wave profile is a safe one to adopt, for strength and other calculations, since it leads to severe conditions, and, for this reason, it is useful to consider what characteristics such a wave should possess. So far as strength calculations are concerned, the relation between the height and the length is the important factor. Many observations have been made of waves at sea, and the accompanying Table V, from Cornish's work,* may be quoted.

TABLE V.

Wind Speed, Metres Per Sec.	Wave Speed, Metres Per Sec.	Wave Period.	Wave Length.	Height.	$\frac{\text{Length}}{\text{Height}}$.
14	11	7	66 m. (215 ft.)	6·6 m. (21·5 ft.)	10
22	18	11·4	204 m. (670 ft.)	10·7 m. (35·0 ft.)	19
30·4	34·3	15·5	376 m. (1,230 ft.)	14·5 m. (47·5 ft.)	25·9

A recent paper by Weinblum and Saint-Denis, "On the Motion of Ships at Sea,"† includes several diagrams from which it is apparent that a young wave, i.e., one which has a speed of about a quarter of the wind velocity, may have a ratio of height to length of 1 : 10; but in general this only applies to short waves, i.e., those under 140 m. long. A curve prepared from observations made by the Scripps Institute of Oceanography in the North Pacific Ocean gives the certain values for most extreme conditions over a long period of time for that ocean which are shown in Table VI, herewith; it is emphasised that the figures do not represent limiting heights of long waves, for instance, those in the North Atlantic. Finally, some results taken from Schnadel's paper may be cited; they are given in Table VII, herewith. These results show that the ratio of length of wave to height is not constant, but tends to increase with length of wave.

We may conclude, therefore, that, while the sea is generally confused during a storm, on occasion a regular wave may be encountered, and that, as Vivet assumed, the height does not bear a constant relation to the length of the wave. It is now necessary to consider what stresses are imposed on a ship at sea by the action of the waves, and whether they can be related to the theoretical stresses calculated on the usual assumptions. It was mainly to answer this question that the experimental voyages of the San Francisco and the Ocean Vulcan were undertaken, and it is unfortunate for the purposes of this paper that, so far, only a preliminary report of the later one, which was carried out with all the resources of modern science at its disposal, has been published. It is therefore necessary to rely almost completely on the San Francisco results, a note on which has already been given before this Congress‡. During the voyage, storms were encountered in which the wind force reached 12 on the Beaufort scale and the vessel was forced to lie to. In this period, the most useful stress readings were recorded, and these were converted to bending moments by multiplying them by the section modulus. Incidentally, no allowance was made for rivet holes, a practice which has been amply justified by the results in the still-water bending-moment experiments on the Neverita and Newcombia. In presenting his information, Dr. Schnadel employed the artifice of deriving the "effective wave" from the bending moment. The "effective wave" is a trochoidal wave of the length of the ship, having such a height that it will induce a bending moment equal to that induced by the actual confused storm waves. The essential result obtained is that the greatest effective wave height for the ship on the wave crest is L/23·5, and when in the hollow, L/18. The extreme value found for the ship in the sagging condition was due to an impact, which increased the moment.

In general, Schnadel concluded that the greatest stresses are sustained when the ship is in the trough of the wave (here the stresses are accentuated by impacts, which always result in an increased compression of the deck and tension of the bottom); the greatest "effective wave" height derived for a ship on the crest of a wave was L/23·5, and for a ship in the trough L/18; the maximum hogging moment was not found with the longest wave, but with waves the height of which is greatest within the ship's length; the effective wave height is less than would result from the application of the Smith correction to the actual wave; hogging stresses may be increased when steaming against wind and waves; and dynamic stresses are not great, but such stresses are a function of the speed of the ship in relation to that of the waves.

Putting the matter in another way, the results show that the maximum tensile stress on the upper deck of the San Francisco in the storm was 550 kg. per square centimetre (3·5 tons per square inch), and the maximum compressive stress 850 kg. per square centimetre (5·4 tons per square inch). These stresses were superimposed on the still-water stress of 550 kg. per square centimetre (3·5 tons per square inch) tensile. For the Ocean Vulcan the preliminary report notes that, during one voyage, when the ship was hove to in a gale of force 8 with waves 165 m. (550 ft.) long by 9 m. (30 ft.) to 10·5 m. (35 ft.) high, the stress due to the wave at times exceeded ±625 kg. per square centimetre (4 tons per square inch); the still-water stress on that occasion, which appears to have been a ballast voyage in the North Atlantic in winter, is not given. It should be remarked that these two ships were of the same type. The dimensions and characteristics are as follows:—

TABLE VI.

Wave Length.		Height.		$\frac{\text{Length}}{\text{Height}}$.
Metres.	Feet.	Metres.	Feet.	
60	200	5·4	18·0	11·0
110	330	9·0	29·5	11·0
140	460	12·0	39·0	11·7
180	590	13·0	43·0	14·0
220	720	11·2	37·0	19·7

TABLE VII.

Wind Speed, Metres per Sec.	Height.		Length.		$\frac{\text{Length}}{\text{Height}}$.
	Metres.	Feet.	Metres.	Feet.	
8	70	230	7·5	24·5	9·3
30	180	590	13·5	44·0	13·3
12	200	660	18·5	61·0	10·8
	130	425	9·1	30·0	14·3
	186	610	16·8	55·0	11·1

"SAN FRANCISCO."

Dimensions—131·0 m. (430 ft.) × 18·0 m. (57 ft.) × 11·5 m./9·06 m. (37·7 ft./29·7 ft.)

Displacement—13,070 tonnes (12,900 tons)
Draught—7·25 m. (28·8 ft.)
Block coefficient—0·744
} When stresses were recorded

"OCEAN VULCAN."

Dimensions—127 m. (416 ft.) × 17·3 m. (56·8 ft.) × 11·35 m./8·72 m. (37·3 ft./28·6 ft.)
Displacement—13,950 tonnes (13,750 tons)
Load draught—8·18 m. (26·8 m. ft.)
Block coefficient—0·763.

From this information we can say, therefore, that, for ships about 130 m. (420 ft.) long, with block coefficients of about 0·76, stress due to the waves reaches a magnitude of about 700 kg. per square centimetre (5 tons per square inch). It is also apparent that the Smith correction does not account for the whole difference between the effects of the actual and the theoretical wave, and that the expedient adopted by Schnadel—that of deriving the "effective wave" from the bending moment—demonstrates the uncertainty of the matter. In his work, Schnadel emphasises very properly that the influence of the size and speed of the ship on the "effective wave" can only be learned by further measurements on ships of a different type. The larger and faster cargo or passenger ships may experience very different effects.

It is open to doubt, furthermore, that small variations in the form of the ships, which may affect the calculated wave bending moment, will greatly influence the actual stresses experienced. The block coefficient, for instance, has an important effect in the theoretical calculation and, as has been indicated, when the block coefficient is reduced the wave bending moment and hence the stresses are reduced also. But the lower block coefficient is associated with the higher speed, and it is difficult to think that the dynamic effects are not increased thereby. It seems probable, therefore, that these factors cancel out. If this is so, the stress resulting from the passage of the wave will not differ greatly between the full and the fine ship. The most that can be said about these wave stresses is that they may bear some relationship to the stresses calculated by assuming that the ship is poised on a static wave. From a large number of calculations of static wave, it seem reasonable to think that the stresses due to the wave vary with length of ship in the following way:

Length—			
m.	91·5	122·0	137·0
ft.	(300)	(400)	(450)
Stress—			
Kg. per sq. cm. ...	550	650	700
Tons per sq. in. ...	(3·5)	(4·1)	(4·5)

These wave stresses, it may be emphasised, are additions to the still-water stresses, determined to a great extent by the disposition of the cargo in the ships, and it is certain that the still-water stresses may vary considerably. For example, in a normal condition of loading, the stress in the upper deck of a 122 m. (400 ft.) ship among waves may be 1,100 kg. per square centimetre (7 tons per square inch), which may be split up into a still-water stress of 450 kg. per square centimetre (2·9 tons per square inch), assuming the cargo is homogeneously loaded, and a wave stress of 650 kg. per square centimetre (4·1 tons per square inch). If the cargo is not loaded in a homogeneous manner, the still-water stress may well rise to 650 kg. per square centimetre (4·1 tons per square inch) or over, giving a total stress of 1,300 kg. per square centimetre (8·2 tons per square inch) or more.

For the same external conditions of heavy weather, the stress due to the wave will be constant and hence the total stress will be governed by the still-water stress. It is suggested, therefore, that the relative strength of a ship may best be judged from the stresses induced in still water and not from the total stress. The still-water component of the stress can be calculated and used as a basis of comparison; the wave component is, to a much greater extent, an uncertain quantity.

We are, therefore, drawn to the conclusion that, in the present state of knowledge, the only precise standards of stress are those sustained by the ship in still water. These are due to the form and characteristics of the ship and to the loading. It has been emphasised already that, in the modern dry-cargo ship, the still-water bending moment is almost invariably a hogging one, and here it may be observed that such was the case in the San Francisco on the occasions to which reference has been made.

It has been shown, also, that the still-water stress for the family of ships considered does not vary greatly, and is of the order of 475 kg. per square centimetre (3·0 tons per square inch) tensile on the upper deck when the ship is homogeneously loaded, and the bunkers are half consumed. Departures from this ideal condition will affect these stresses to a greater or lesser extent, and experience has shown that, with injudicious loading, they may be greatly exceeded. The author is of the opinion, therefore, that the most reasonable and most direct method of comparing, in similar ships, stresses induced in service is to consider the stresses calculated in the still-water condition and not those derived from the conventional assumption that the ship is poised on a wave.

APPENDIX.

Variation of B.M. with length of wave.—This variation has been computed from a formula which applies to a wall-sided ship, with a waterline bounded by a parabola, and a wave of cosine form. If m is index of parabola, $p\,\mathrm{L}$ is length of wave, and h is height of wave; then, for a ship on the crest of a wave,

Volume of wave

$$= \int \frac{\mathrm{B}\,h}{2}\left[1 + \cos\frac{\pi x}{p\,\mathrm{L}} - \frac{x^m}{\mathrm{L}^m} - \frac{x^m}{\mathrm{L}^m}\cos\frac{\pi x}{p\,\mathrm{L}}\right]. \quad (1)$$

Moment of wave

$$= \int \frac{\mathrm{B}\,h}{2}\left[x + x\cos\frac{\pi x}{p\,\mathrm{L}} - \frac{x^m + 1}{\mathrm{L}^m} - \frac{x^m + 1}{\mathrm{L}^m}\cos\frac{\pi x}{p\,\mathrm{L}}\right] \quad . \quad . \quad . \quad (2)$$

Evaluating,

$$\text{Volume} = \frac{\mathrm{B}\,h\,\mathrm{L}}{2}\left[1 - \frac{1}{m+1} - \frac{p^2}{\pi^2}\left(\cos\frac{\pi}{p}\right)m + \frac{p^3}{\pi^3}\left(\sin\frac{\pi}{p}\right)m\,(m-1) + \frac{p^4}{\pi^4}\left(\cos\frac{\pi}{p}\right)m\,(m-1)\,(m-2) - \frac{p^5}{\pi^5}\ \ldots \text{ etc.}\right.$$

* *Ocean Waves*, by V. Cornish (1935).

† "On the Motions of Ships at Sea," by G. Weinblum and M. Saint-Denis. *Trans. Soc. Nav. Arch. and Mar. Engineers, New York*, 1950.

‡ "Beanspruchungs Messungen om Bord," by Dr. G. Schnadel. *Proc. Cong. International des Ingenieurs Navals*, 1939.

$$\text{Moment} = \frac{B\,h\,L^2}{2}\left[\tfrac{1}{2} + \frac{p^2}{\pi^2}\left(\cos\frac{\pi}{p}\right) - \frac{1}{m+2}\right.$$
$$- \frac{p^2}{\pi^2}\cos\frac{\pi}{p}(m+1) + \frac{p^3}{\pi^3}\sin\frac{\pi}{p}(m+1)(m)$$
$$+ \frac{p^4}{\pi^4}\cos\frac{\pi}{p}(m+1)(m)(m-1) - \frac{p^5}{\pi^5}\ \ldots \text{ etc.}$$

The centre of gravity of the original layer from which the wave is evolved is $\frac{m+1}{2(m+2)}$ and therefore the change in moment can be found.

TABLE VIII.—*Values of b at Load Draughts.*

Wave Bending Moment = $b\,L^3\,B \times 10^{-5}$ (metric units)
$b\,L^3\,B \times 10^{-6}$ (English units)

Block Coeff.	Hogging.		Sagging.	
	Metric.	English Units.	Metric.	English Units.
0·76	84·5	23·55	95·0	26·50
0·74	82·0	22·85	92·0	25·70
0·72	79·0	22·10	89·5	24·90
0·70	76·5	21·35	86·5	24·10
0·68	74·0	20·65	83·5	23·35
0·66	71·5	19·90	81·0	22·60

For a wave having a height of $\frac{1}{20}$th of its length, the constant b should be multiplied by the following factors:

Length of Wave / Length of Ship.	Factor.
0·6	0·50
0·7	0·73
0·8	0·89
1·0	1·00
1·2	1·01
1·4	0·98
1·6	0·88
1·8	0·86
2·0	0·88

These factors may be applied to ships having block coefficients varying from 0·70 to 0·75.

CONTRACTS.

LEONARD FAIRCLOUGH, LTD., 52, Grosvenor-gardens, London, S.W.1, have been awarded the contract for the widening of bridge No. 14 carrying Abbots-avenue over the London Midland Region line of British Railways between Park Street and St. Albans Abbey stations, for the St. Albans City Council.

DURING September the British Electricity Authority have placed contracts for equipment for power stations, transforming stations and transmission lines amounting, in the aggregate, to 2,742,163*l*. The principal contracts include a 240,000-lb. per hour boiler and coal-transportation plant for Acton Lane "B" power station, Willesden, with MITCHELL ENGINEERING, LTD.; coal-unloading cranes for Tilbury power station, with STOTHERT AND PITT, LTD.; a cooling tower for Drakelow power station, Burton-on-Trent, with the MITCHELL CONSTRUCTION CO.; high-pressure pipework and valves for Meaford "B" power station, near Stone, Staffordshire, with BABCOCK AND WILCOX, LTD., and auxiliary switchgear and accessories for the same station, with A. REYROLLE & CO., LTD.; high-pressure steam piping for Stourport "B" power station, with AITON & CO., LTD.; general transformers for Connah's Quay power station, Chester, with C. A. PARSONS & CO., LTD., and auxiliary switchgear for the same station, with A. REYROLLE & CO., LTD.; 3,300-volt auxiliary switchgear and accessories for Chadderton power station, Oldham, with the ENGLISH ELECTRIC CO., LTD.; a condensing-water system for Roosecote power station, Barrow, with BIERRUM & PARTNERS, LTD.; 132-kV 2,500-MVA switchgear for Goldington power station, Bedford, with A. REYROLLE & CO., LTD.; 132-kV 2,500-MVA switchgear for Three Bridges substation, Sussex, with the ENGLISH ELECTRIC CO., LTD.; and 132-kV 3,500-MVA switchgear for Stella South, Blaydon-on-Tyne, with A. REYROLLE & CO., LTD.

FLETCHER & CO. (CONTRACTORS), LTD., Mansfield, are to supply new substructure and filling for bridges 16 and 21 on the Stanton and Shipley branch and Stanton and Nutbrook branch of the London Midland Region of British Railways.

VICKERS-ARMSTRONGS LTD., Vickers House, Broadway, London, S.W.1, announce the receipt of another repeat order from Alfred Holt & Co., for an 8,300-ton single-screw cargo motorship. She will be built at the Naval Yard, Newcastle-upon-Tyne; her length, between perpendiculars, will be 452 ft. 9 in., her beam 62 ft., and her depth 35 ft. 3 in. The propelling machinery will consist of a B. & W. Diesel engine to be built by HARLAND & WOLFF, LTD., and installed by the builders of the ship. The vessel's service speed will be 16 knots.

LABOUR NOTES.

"UNANIMOUS opposition" by the Scottish area of the National Union of Mineworkers to the proposed terms for the new supplementary pension scheme for coal miners was reported by Mr. Abe Moffat, the President of the union's Scottish area, at a meeting in Edinburgh on Monday last. He said that the Scottish miners considered that the pensions which would be payable under the scheme were inadequate. The men also felt that the proposed contributions from the National Coal Board to the pension fund were insufficient. Another objection by Scottish miners to the scheme in its present form was that former miners, who had retired prior to the nationalisation of the industry, were not included. The scheme provided for pensions, varying from 10*s*. to 30*s*. a week, for miners, aged 65 years and over, on their retirement; the sums depending upon the years of service and good-attendance records of the recipients. Maximum pensions of 45*s*. a week would eventually become payable to men who worked in the mines for 45 years from the inauguration of the scheme, but, Mr. Moffat pointed out, only miners who were eighteen years old when the scheme was put into operation could hope to qualify for pensions of that amount. Service in the industry previous to the coming into force of the scheme would count only for the 10*s*.-a-week pension.

Branches of the National Union of Mineworkers throughout the country have been taking a vote recently on whether or not the scheme, which is a joint effort by the National Coal Board and the union to provide supplementary pensions for employees in the industry, should be accepted. The voting closed on Monday and the final figures were due to be reported to the national executive of the union yesterday. It was expected that the voting would show that the scheme was acceptable to all areas of the union other than Scotland and Kent. In that case, the scheme would come into force on January 1, 1952, and supplementary pensions would begin on that date. It was estimated that some 20,000 ex-miners would be eligible. If the scheme is to achieve the results hoped for by the N.C.B. and the union, it would appear to be essential that the dissentients should fall into line with the decision of the majority, as recorded by the recent voting.

Negotiations between the National Coal Board and the National Union of Mineworkers on the union's claims for further advancements in the wages of mine employees were begun in London on Wednesday last. Among the demands put forward by the union and considered at the joint meeting were an increase of 23*s*. a week for underground miners engaged on a day-wage basis, an advance of 3*s*. a shift for employees working on piece-rate terms, and the raising of the national minimum rates for surface employees by 20*s*. a week. The demands, if conceded in full, would bring the standard wage of underground miners up to 7*l*. 10*s*. a week, and that of surface employees up to 6*l*. 10*s*. a week. It was estimated that the cost of such concessions by the N.C.B. would result in an addition of at least 35 million pounds to the Board's annual wage bill. The results of the joint meeting were not available at the time of going to press, but it was considered likely that the Board, while not prepared to meet the union's demands in full, would offer to make some increases in miners' wages.

The Railway Staff National Tribunal will meet on October 19 to commence its investigations on the joint claim of the three principal railway unions for an all-round wage increase of 10 per cent. Sir John Forster, K.B.E., K.C., who is also President of the Industrial Court, will be the chairman of the Tribunal. The other members of the Tribunal will be Sir Graham Cunningham, K.B.E., a member of the Economic Planning Board since 1947, and Sir Luke Fawcett, O.B.E., who was for many years the general secretary of the Amalgamated Union of Building Trade Workers of Great Britain and Ireland. The hearings in respect of the claim will take place at the Railway Clearing House, St. Pancras, London, N.W.1, and will be open to the public.

Some progress towards a settlement has been made in connection with two stoppages which arose last week. About 1,400 workpeople engaged at the Foleshill factory, Coventry, of the Dunlop Rim and Wheel Company, Limited, went on strike on October 3, as the result of a dispute over the rates of pay for labourers employed by the firm. They returned to work on Monday last, however, on the assurance that their grievance would be carefully investigated.

More than two hundred crane men employed at the larger shipbuilding and ship-repairing yards in the Glasgow area ceased work on October 5, in order to enforce a claim for an advance in wages. On Monday last, it was reported that the strike had spread to a few of the smaller shipyards in the same district and that most shipbuilding establishments on the Clyde were affected in some way by the strike. An appeal was made to the crane men on the same day by an official of the National Union of General and Municipal Workers, to which the men belong, that they should return to work immediately, to enable negotiations to be commenced. This advice was rejected, and the men decided by a large majority that they would not resume work until Tuesday next, the day before the date fixed for a joint meeting in London between the union's officials and representatives of the employers' organisation. In the event of the joint meeting taking place earlier than Wednesday, however, the crane men agreed that there should be a return to work on the day before the revised meeting date.

The Transport and General Workers' Union reports that it has been successful in securing increases of $4\frac{1}{2}d$. an hour for all adult employees, men and women, covered by the engineering and maintenance repair panel of the civil air-transport industry. A measure of consolidation of the rates for overtime, sickness, holidays, and pensions has also been achieved by the union on behalf of employees covered by the panel, and some increases in the payment for these items will result. The adjustments became effective on September 16 last. The claim of the T.G.W.U. for an increase of 4*d*. an hour for employees in the iron, steel and non-ferrous scrap-metal trades will be considered at a joint meeting between officials of the union and representatives of the employers' organisations on Tuesday next. A meeting has also been arranged between the union's officials and representatives of the British Aluminium Company, Limited, London, E.C.2, to discuss the union's claim for an increase of 20*s*. a week in the wages of all adult persons employed by the company. Cost-of-living increases for employees in the wire-rope industry will be considered at the next meeting of the industry's joint industrial council.

Wage claims on behalf of men employees in the engineering industry were discussed at a joint meeting in London between representatives of the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions on Wednesday last. The demands, for an all-round increase of 20*s*. a week, were originally put forward by the Amalgamated Engineering Union and later sponsored by the Confederation. The employers' Federation undertook to give careful consideration to the Confederation's case and it was tentatively arranged that a further meeting between the two sides should take place on November 14, to receive the employers' reply. Parallel claims on behalf of women engineers, and employees in the shipbuilding and ship-repairing industry, are also in process of negotiation. More than two-and-a-half million workpeople are involved in the three claims, which, if granted in full, would add about 125 million pounds a year to the nation's wage bill.

The recent report of the committee on the organisation, working conditions and remuneration of the industrial group of professional civil servants was criticised in a statement issued by the Engineers' Guild on Tuesday last. The Guild described the report as trivial and disappointing, and expressed the opinion that few persons, who had had contacts with the engineering branches of the Civil Service, would agree with the broad conclusions reached by the committee, that the organisation and structure of the Civil Service engineering side were satisfactory. The committee's report was principally concerned with problems affecting engineers in Government employment, a large number of whom are members of the Guild. The Guild was formed in 1938 to promote the interests of the engineering profession and has established its headquarters in London. Membership is open to all corporate members of the Institutions of Civil, Mechanical and Electrical Engineers.

Inspection methods in use at engineering establishments in the United States engaged on mass production will be studied by a party of industrial specialists which left Britain on Tuesday last under the technical assistance scheme of the Organisation for European Economic Co-operation. Three teams, comprising some 80 persons in all, drawn from many branches of the engineering industry are taking part in the scheme. During a six-weeks' stay in the United States, they will tour a wide range of research centres and industrial undertakings, and will investigate galvanising techniques, and non-ferrous heavy-metal fabrication, as well as the smelting and refining of non-ferrous metals. It is understood that the three teams will later go to Paris to undertake the preparation of reports on the results of their studies and that these reports will eventually be circulated among the countries covered by the Organisation for European Economic Co-operation.

CHARACTERISTICS OF CROSS-SPRING PIVOTS.

Fig. 1. 90 DEG. SYMMETRICAL CROSS-SPRING PIVOT

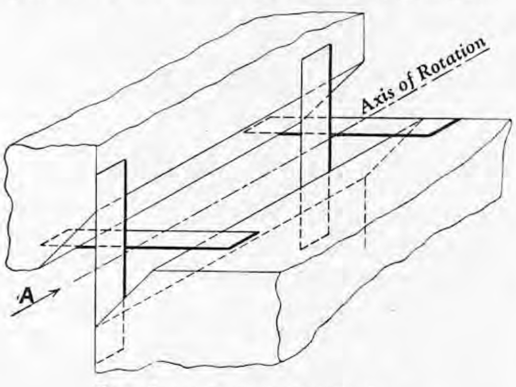


Fig. 2. VIEW IN DIRECTION A

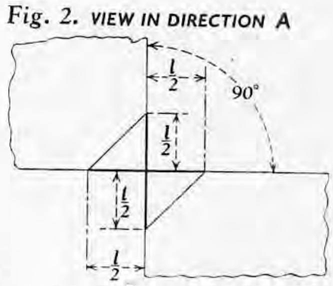


Fig. 3. ADJUSTABLE CROSS-SPRING PIVOT ELEVATION.

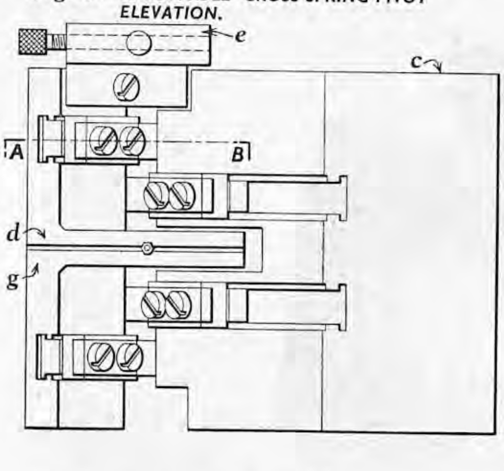


Fig. 4. PLAN.

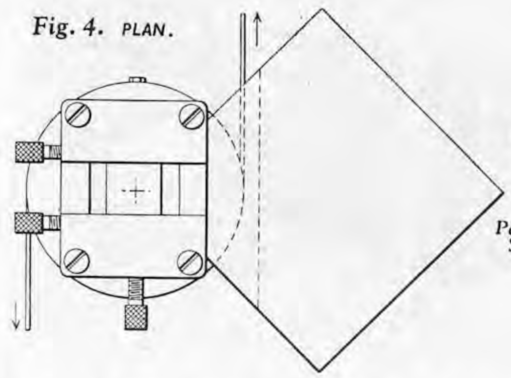


Fig. 5. SECTION A-B.

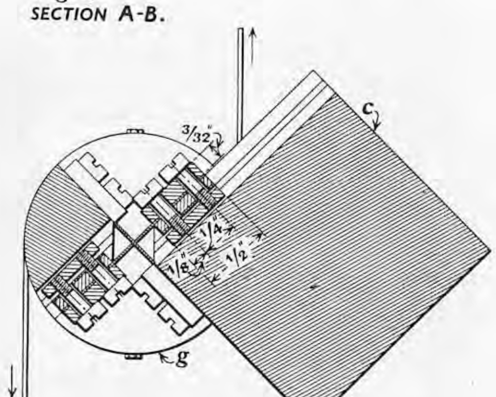


Fig. 6. METHOD OF CLAMPING STRIPS.

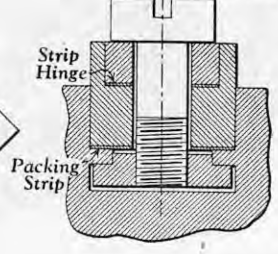
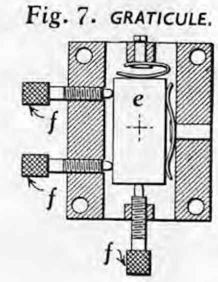


Fig. 7. GRATICULE.



"ENGINEERING"

DESIGN CHARACTERISTICS OF CROSS-SPRING PIVOTS.*

By L. W. NICKOLS, B.Sc. (Eng.), A.M.I.Mech.E., and H. L. WUNSCH, M.Eng., G.I.Mech.E.

THE most common type of cross-spring pivot consists of two pairs of crossed steel strips, of uniform length, width and thickness, which are fixed rigidly at their ends to the two parts between which relative movement is required. A typical example is shown in Figs. 1 and 2, herewith. Such cross-spring pivots have many advantages over pivots embodying plain bearings in the design of engineers' measuring instruments, the externally-applied loads being, in general, insufficiently large to cause failure by buckling of the strips or to cause the cross-spring pivot to become unstable. The main advantages are that the cross-spring pivots are frictionless, and therefore have no hysteresis effect, are not subject to wear and require no lubrication. These pivots are not always suitable, however, for large angles of rotation because of the shift of the axis of rotation at these large angles. This disadvantage is of minor importance in measuring instruments, where the angles of rotation are small and rarely exceed 15 deg. of arc.

Theoretical investigations of the design characteristics of the cross-spring pivot, i.e., the relationship between the geometric dimensions of the pivot and its stiffness and the movement of the initial axis of rotation, have been carried out by a number of workers, including Eastman, Wittrick and Haringx.† In general, these investigations are mathematically complex and little practical work seems to have been done to check their results. A practical investigation by Young‡ was concerned with spring strips having a functional length l (see Fig. 2) exceeding 1 in., and was therefore not necessarily applicable to instrument practice, where the functional length of the spring strips is usually less than $\frac{3}{4}$ in.

The present investigation was carried out in order to provide information of use to designers wishing to incorporate cross-spring pivots in their instruments, and therefore the sizes used were kept within the range usually employed for this purpose. The work described relates to the type of cross-spring pivot most commonly used, in which the cross strips intersect at 90 deg. at the mid-point of their functional lengths (Figs. 1 and 2), i.e., to the 90-deg. symmetrical cross-spring pivot. To a lesser degree, asymmetrical cross-spring pivots are also used, and it is intended to extend the work to this type. As a first approach to the problem, the effect of pure torque on cross-spring pivots has been investigated. The effect of externally-applied loads on the characteristics of cross-spring pivots is being investigated at present, but this aspect is not dealt with here.

An adjustable cross-spring pivot which was designed to take different lengths and thicknesses of steel strip is shown in diagrammatic form in Figs. 3 to 7, herewith. It consists of a fixed part c to which is attached a movable part d by means of two pairs of spring strips. The movable part d is made of aluminium alloy in order to reduce to a minimum the effect of its weight on the system, and carries on its upper face a glass graticule e having an inscribed cross line (Fig. 7). This graticule is adjustable in two directions at right-angles, by means of the set screws f, and the cross line can therefore be accurately aligned with the intersection of the neutral axes of the spring strips. The central portion g of the movable part d is cylindrical in form, and the couple is applied by two equal and opposite loads, as shown in Figs. 4 and 5.

The ends of the spring strips are held in position by the arrangement shown in Fig. 6, consisting of clamping pieces and two set-screws passing through clearance holes in the strip. This arrangement permits the use of packing strip of a suitable thickness to ensure that the neutral axes of the spring strips always intersect on the longitudinal axis of the cylindrical part g by means of which the torque is applied. The clearance holes in the spring strips were either punched or drilled, the strip in the latter case being held between two pieces of metal plate and a hole drilled through the sandwich so formed; this prevented any distortion of the spring strip. The clamping pieces slide in T-slots, so that spring strips having functional lengths up to $\frac{3}{4}$ in. may be used. The apparatus as constructed will take spring strips of $\frac{1}{4}$ in. width and up to 0·020 in. in thickness. With minor modifications, spring strips of greater thicknesses could be tested.

The complete arrangement of the apparatus is illustrated in Fig. 8, on page 474. From this it will be seen that the fixed part c of the apparatus is securely clamped to the table of a toolmaker's microscope, having co-ordinate movements operated by micrometers which can be read to about 0·0001 in. A goniometric scale in the eyepiece of the microscope allows readings of rotation of the cross line on the graticule e to be taken to approximately 1 minute of arc. Torques are applied to the system by nylon threads attached to g and running over pulleys clamped to a wooden table, which is placed around the instrument. Scale pans are attached to the ends of the nylon threads, and addition of equal weights to each scale pan produces a pure torque on the cross-spring pivot. When experiments were first started, friction in the pulleys caused much trouble, especially in the case of small torques, but the fitting of ball bearings to the pulleys eliminated most of this trouble.

The accuracy of setting of the two pairs of spring strips, prior to clamping in position, is of great importance. Any tendency to twist the spring strips during clamping will materially affect the characteristics of the pivot and may also cause the spring strips to buckle. The lengths of the spring strips between the clamping pieces should be equal, and the intersection of the neutral axes of each pair of strips should lie on a common axis of rotation half-way along their lengths (for symmetrical cross-spring pivots). The required accuracy of setting was achieved by the use of two setting jigs, one of which is illustrated in Figs. 9 and 10, on page 474. By assembling the jigs with the upper and lower parts of the cross-spring pivot, the fixed part c and the movable part d are held rigidly in alignment with each other. Each spring strip is then set in its correct position to an accuracy of 0·001 in. by inserting slip gauges between the body of the apparatus and the end face of the appropriate clamp; the latter is then tightened in position. After the spring strips have been set correctly in position, the jigs are removed and the apparatus mounted on the table of the toolmaker's microscope. By focussing on the four spring strips in turn and using the graticule adjusting screws, the cross-line on the graticule e (Fig. 7) is brought in line with the initial axis of rotation of the cross-spring pivot. This, in turn, is brought into line with the cross-wires in the microscope eyepiece. Any movement of the initial axis of rotation can now be observed and measured.

A series of torques was applied to the movable part d of the cross-strip pivot, and, for each torque, measurements of the angle of rotation of d were made by means of the goniometric scale in the microscope eyepiece. Also, the lateral shift of the initial axis of rotation was measured by bringing the cross-line on graticule e into coincidence with the cross-wires in the microscope eyepiece by means of the co-ordinate movements of the table. The torques on each size of cross-spring pivot were restricted to a maximum of 6 lb.-in.* It was considered that torques greater than this value were unlikely to be used in engineers' measuring instruments, and, in fact, a torque of 6 lb.-in. was reached only on the shorter lengths of the 0·015-in. and 0·020-in. thick spring strip, giving rise to angular rotations of 8 deg. for the 0·158-in. length of 0·015-in. spring strip, and angular rotations of 4 deg. and 7 deg., respectively, for the 0·158-in. and 0·410-in. lengths of 0·020-in. spring strip. In the case of the thinnest spring strips, rotations of 35 deg. to 45 deg. were

* Communication from the National Physical Laboratory. The work was carried out as part of the research programmes of the Mechanical Engineering Research Organisation and the National Physical Laboratory, and the article is published by permission of the Directors.

† "The Design of Flexure Pivots," by F. S. Eastman, *Jl. Aeronaut. Sci.*, vol. 5, pages 16 to 21 (November, 1937); "The Theory of Symmetrical Crossed Flexure Pivots," by W. H. Wittrick, *Austral. J. Sci. Res.* Series A, Physical Sc., vol. 1, pages 121 to 134 (1948); and "The Cross-Spring Pivot as a Constructional Element," by J. A. Haringx, *Appl. Sci. Res.* (A1), pages 313 to 332 (1949).

‡ "An Investigation of the Cross-Spring Pivot," by W. E. Young. *Jl. Appl. Mech.*, vol. 11, page A 113 (1944).

* 1 lb.-in. = 1·1525 kg.-cm.

CHARACTERISTICS OF CROSS-SPRING PIVOTS.

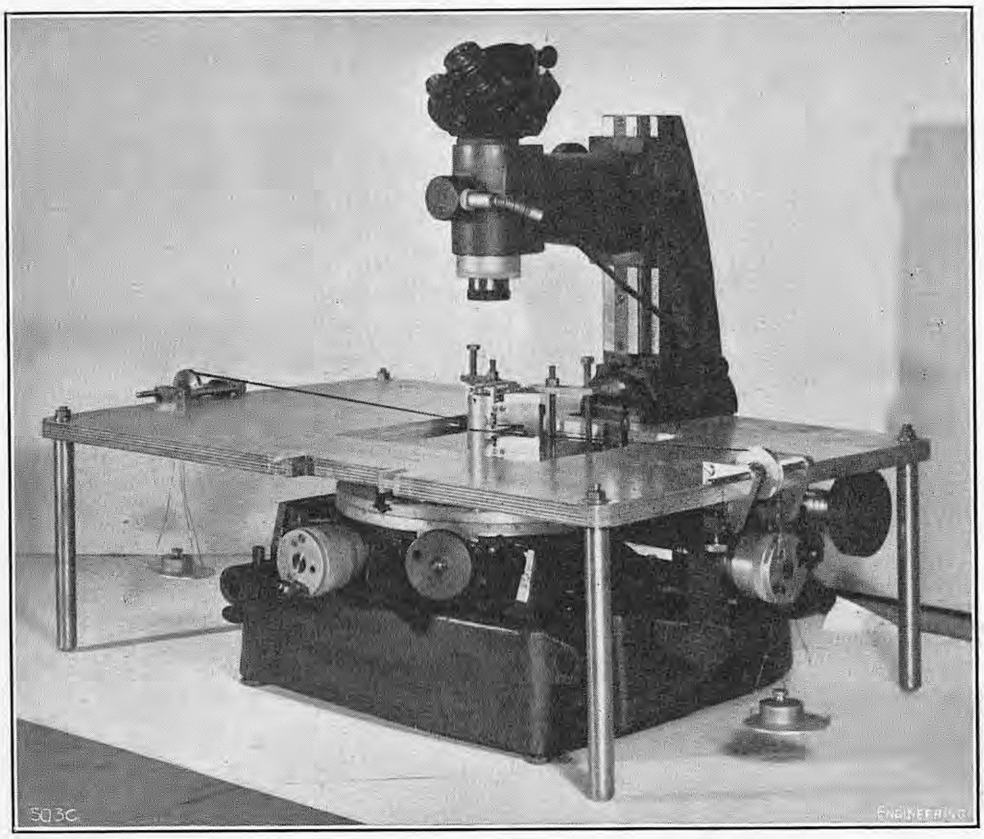


FIG. 8. CROSS-SPRING PIVOT MOUNTED ON TOOLMAKER'S MICROSCOPE.

Fig. 9. SETTING JIG

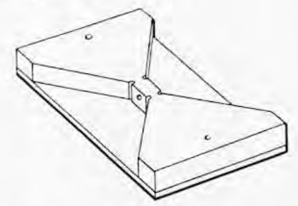
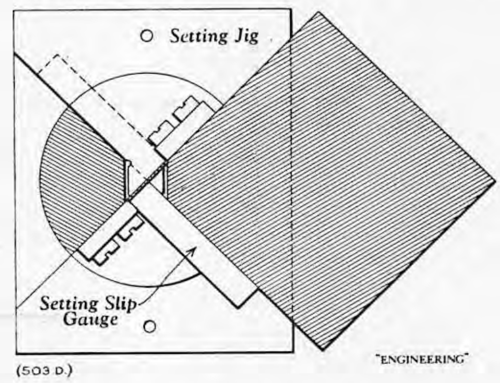


Fig. 10.
ADJUSTING CROSS-SPRING PIVOT



obtained. Measurements were then taken with decreases in torque from the maximum value. Two complete sets of readings were taken for each cross-spring pivot, the spring strips being dismantled and re-assembled between the two sets; this provided information about the effect of slight differences in clamping and setting.

Altogether, five thicknesses of spring strip were used, of the following nominal sizes: 0·005 in., 0·0065 in., 0·010 in., 0·015 in., and 0·020 in. In some cases, the actual thickness was found to vary by as much as 0·001 in. from the nominal value, and allowance was made for this departure from nominal size when analysing the results. Each of these spring strips was made in the three following functional lengths: 0·158 in., 0·410 in., and 0·660 in.

For any one size of cross-spring pivot it was found that the angular rotations produced by the series of progressively increasing torques were very similar to those produced by the same torques progressively decreasing from the maximum value. In other words, the hysteresis effect was negligible, as was to be expected. The mean values of the angular rotations for each setting were then plotted against the applied couple. As measurements were obtained for two settings for each size of cross-spring pivot, two sets of values were plotted on each graph, as shown in Fig. 11, opposite. These two sets of values were in such good agreement that no difficulty was experienced in drawing a mean line representing the performance of that size of pivot. This close agreement indicated that the accuracy with which the spring strips could be set in position by the method already described was completely satisfactory.

The graphs of angular rotation plotted against applied couple indicated in every case that the angle of rotation was very nearly proportional to the applied torque. A slight increase in stiffness, i.e., the applied couple per radian deflection, was found in the case of 0·0050-in. spring strips, at the larger angles of rotation, but this was small enough to be neglected in practice. From the experimental results, the stiffness was calculated for the different combinations of length and thickness of the spring strips and plotted against the spring-strip thickness, as shown by the full-line curves in Fig. 12, opposite.

For each of the three lengths of spring strip investigated, a graph of the movement of the initial axis of rotation per inch length of spring strip was plotted against angle of rotation, as shown by the full-line curves in Fig. 13. It was found that the actual movement of the initial axis of rotation of any of the cross-spring pivots investigated was less than 0·003 in. for angular rotations up to about 10 deg. For greater angular rotations the movement increased considerably, reaching a value of 0·06 in. for a 50-deg. rotation of a cross-spring pivot 0·66 in. long and 0·005 in. thick.

To determine an empirical formula relating the stiffness and geometric size of cross-spring pivots,

Let b = width of single strip (in.).
d = thickness of strip (in.)
I = moment of inertia of normal section of single strip about its neutral axis = $\frac{b\,d^3}{12}$ (in.^{4}).
l = length of strip (in.).
E′ = effective Young's Modulus for the material of the strip, taken as $27 \cdot 5 \times 10^6$ lb. per square inch. (The measured values for E range from $27 \cdot 2$ to $29 \cdot 2 \times 10^6$ lb. per square in.).
K = stiffness of pivot (lb.-in. per radian).

The theoretical relationship between stiffness K and geometrical dimensions of the strip is of the form:

$$K = X\frac{E'\,I}{l}, \text{ where X is a constant.} \quad (1)$$

Values of X were calculated for each of the 15 sizes of spring strips, using the experimentally-determined values of K, and the values obtained are given in Table I.

TABLE I.—*Experimental Values of X for Various Cross-Spring Pivots.*

Length of Spring Strip.	Thickness of Spring Strip.	Stiffness of Cross-spring Pivot.	Experimental Value, $X = \frac{K\,l}{E'\,I}$.
l, in.	d, in.	K, lb.-in. per rad.	X.
0·158	0·0055	1·92	2·917
	0·0066	3·51	3·086
	0·0100	12·37	3·127
	0·0157	44·47	2·905
	0·0190	82·91	3·056
0·410	0·0051	0·67	3·313
	0·0067	1·51	3·293
	0·0102	5·23	3·233
	0·0158	20·45	3·401
	0·0198	39·50	3·338
0·660	0·0054	0·54	3·621
	0·0067	0·95	3·336
	0·0100	3·39	3·580
	0·0158	12·94	3·464
	0·0188	22·67	3·603

This table indicates that there is a general tendency for X to increase with the value of l. Average values of X for each value of l were then calculated and these gave:

l = 0·158 in., X = **3·018**
l = 0·410 in., X = **3·316**
l = 0·660 in., X = **3·521.**

Assuming that the increase of X with l was due to a constant uncertainty in the determination of the effective length of l, it was found that when the factor X in Equation (1) was replaced by the expression $\frac{4\,l}{l + 0 \cdot 035}$, the values calculated from the modified formula agreed to within 1·5 per cent. with the average experimental values. Substituting for X in Equation (1), the following empirical formula was obtained:

$$K = 4\frac{E'\,I}{(l + 0 \cdot 035)}. \quad (2)$$

If b, d and l are expressed in centimetres, and E′ in kilogrammes per sq. cm., then

$$K \text{ (kg.-cm. per radian)} = 4\frac{E'\,I}{(l + 0 \cdot 089)}. \quad (3)$$

Substituting in Equation (2) values of I corresponding to thicknesses of the spring strips intermediate between those actually used, values of K were calculated and plotted on the graph of Fig. 12. It will be seen that close agreement with the curves obtained from the experimental results was secured in all cases.

To determine an empirical formula relating the shift of the initial axis of rotation and the angle of rotation of the cross-spring pivot, let

l = length of strip (in.).
θ = angular rotation of pivot (deg.).
S = shift of initial axis of rotation (in. per in. length of spring strip).

It was assumed that the three experimental curves in Fig. 13, giving the relation between the shift of the initial axis of rotation and the angle of rotation for the lengths of spring strip investigated, have equations of the form

$$S = A\,\theta + B\,\theta^2 \quad (4)$$

where A and B are constants for the length considered. The values of these constants for the cross-spring pivots having 0·158-in. and 0·660-in. lengths of strip, respectively, were determined in the following manner.

For the 0·158-in. cross-spring pivot: From Fig. 13,

$$S = 0 \cdot 000287\,\theta + 0 \cdot 000051\,\theta^2 \quad (5)$$

For the 0·660-in. cross-spring pivot; from Fig. 13,

$$S = 0 \cdot 000064\,\theta + 0 \cdot 000039\,\theta^2 \quad (6)$$

Combining equations (5) and (6), and assuming that the variation with length of the value of S is linear, Equation (7) was obtained:—

$$S = (0 \cdot 000357 - 0 \cdot 000444\,l)\,\theta + (0 \cdot 000055 - 0 \cdot 000024\,l)\,\theta^2. \quad (7)$$

If l is expressed in cm.,

$$S = (0 \cdot 000907 - 0 \cdot 000444\,l)\,\theta + (0 \cdot 000140 - 0 \cdot 000024\,l)\,\theta^2. \quad (8)$$

Values of S were calculated from Equation (7) for

CHARACTERISTICS OF CROSS-SPRING PIVOTS.

Fig. 11.

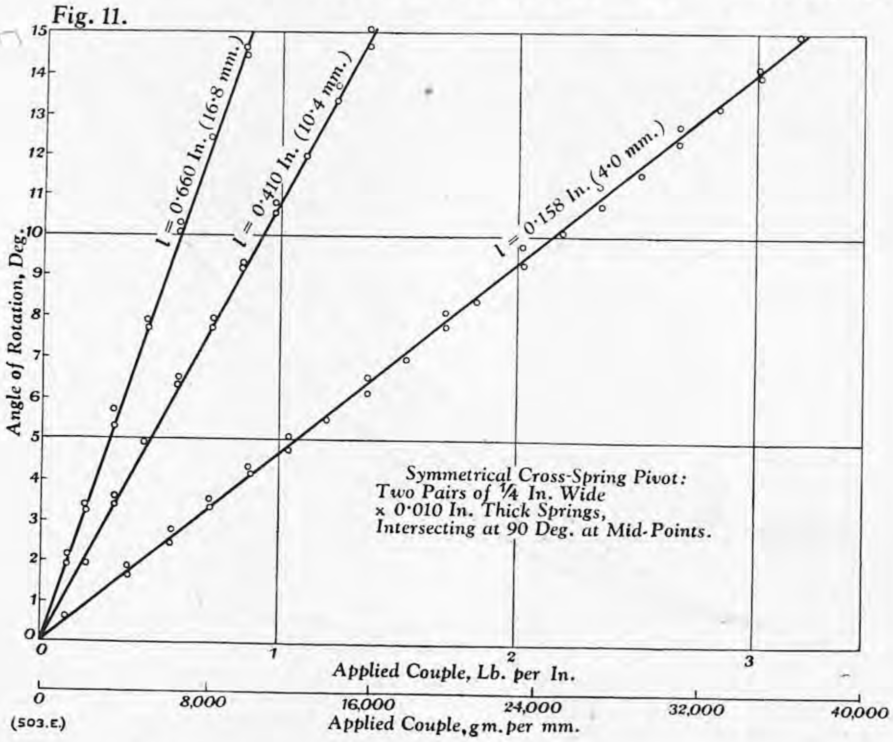


Fig. 12.

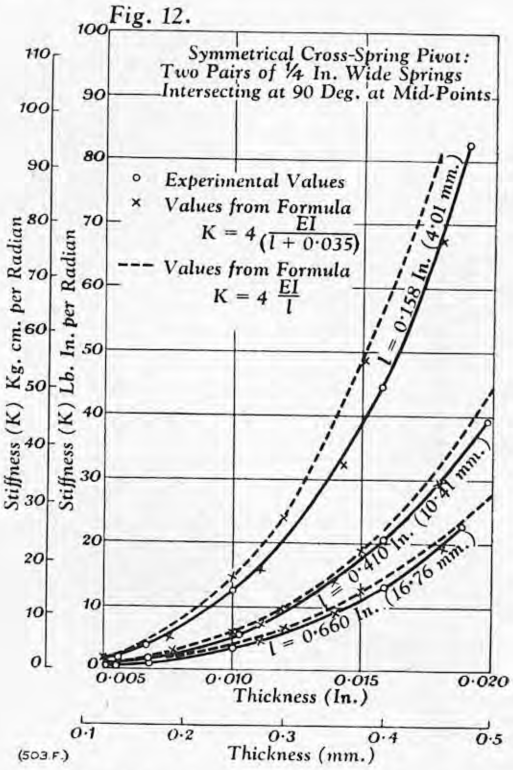
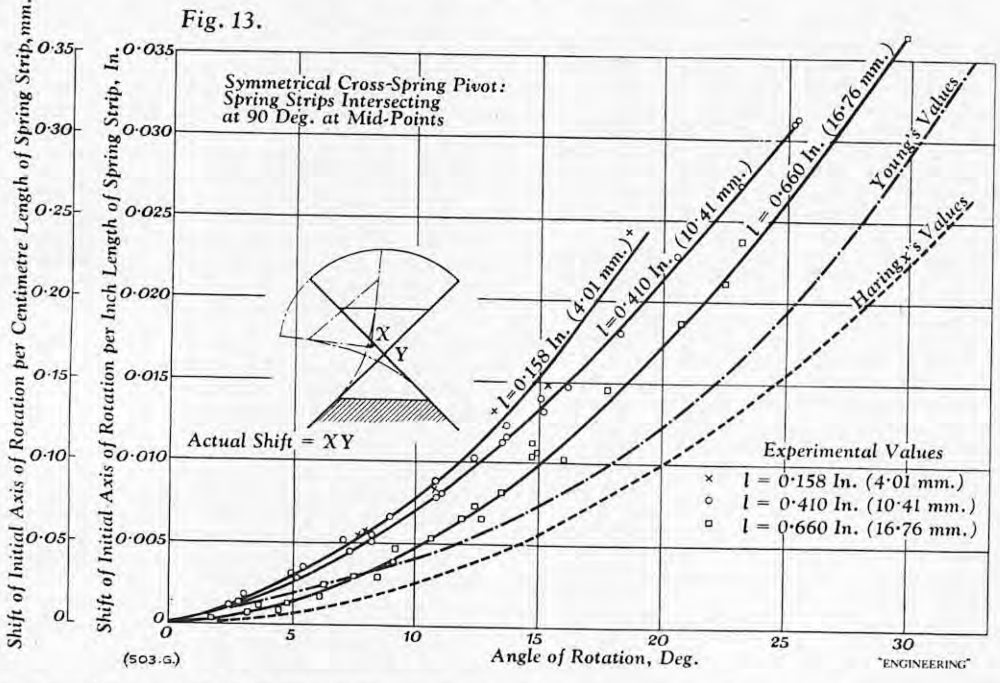


Fig. 13.



various angular rotations of the cross-spring pivots on which the experimental determinations were made. It will be seen from Table II that the empirical formula gives values for S which agree reasonably well with the experimental values.

TABLE II.—*Experimental and Calculated Values of* S.

Length of Spring Strip.	Angle of Rotation.	Shift of initial axis of rotation per inch length.	
		Experimental Values.	Values from Empirical Formula.
l, in.	θ, deg.	S, in.	S, in.
0·158	5	0·0027	0·0027
	10	0·0078	0·0080
	19	0·0237	0·0239
0·410	5	0·0024	0·0020
	10	0·0069	0·0062
	20	0·0214	0·0215
	25	0·0307	0·0325
0·660	5	0·0013	0·0013
	10	0·0047	0·0045
	20	0·0173	0·0169
	29	0·0349	0·0347

Comparing, now, the results of the investigation with the theoretical and experimental investigations of other workers, and considering first the relation between the stiffness and geometric size of the 90-deg. cross-spring pivot, Eastman states that the formula given below and derived from the theory of bending may be applied to symmetrical cross-spring pivots under pure torsion only.

$$\text{Bending moment, M} = n\frac{E' I \theta}{l}$$

$$\text{i.e., stiffness, K} = n\frac{E' I}{l} \quad . \quad . \quad (9)$$

where n = number of spring strips.

Eastman's theoretical analysis gives no restrictions on the use of this formula, except that it applies only to small angles of rotation. In the present investigation, spring strips having lengths up to about $\frac{3}{4}$ in. are used and it is shown that the simple formula (9) is not generally applicable to such short lengths. Fig. 12 shows that formula (9) may give results up to about 25 per cent. in error. The reason for this discrepancy is associated with the fact that the effective length of the strip is greater than its measured length, because of non-rigid clamping.

Most of Wittrick's theoretical analysis applies to cross-spring pivots acted on by external loads, as well as by a torque and is not discussed in this paper. Haringx's theoretical analysis gives values which agree to an accuracy of 4 per cent. with the practical investigation given in this paper, provided the angular rotations are less than 20 deg. Young's work was done on spring strips ranging from $1\frac{1}{2}$ in. to 3 in. in length and from 0·0085 in. to 0·012 in. in thickness. When his empirical formula is applied to the sizes of spring used in the present practical investigation, the results agree to within $7\frac{1}{2}$ per cent. for small angles of rotation.

With regard to the movement of initial axis of rotation, neither Eastman nor Wittrick deals with the movement of the initial axis of rotation of the cross-spring pivot. Haringx, however, has calculated this movement from theoretical considerations and gives the following formula:

$$\begin{array}{l}\text{Movement of initial axis} \\ \text{per inch length of spring}\end{array} = \frac{\sin \theta/2}{\theta/2 \text{ (radians)}} - \cos \theta/2 \quad . \quad . \quad . \quad (10)$$

The values obtained from his formula, expressed as movement of initial axis per inch length of spring strip, are shown by the dotted line in Fig. 13. The experimental results obtained by Young, which are also shown in Fig. 13, led him to the following empirical formula:

$$S \times 10^3 = 0·4133\,\theta - 0·01225\,\theta^2 + 0·001267\,\theta^3 - 0·0000075\,\theta^4. \quad (11)$$

It will be seen that Young's experimental results agree reasonably well with those obtained in the present investigation for small angular rotations up to about 5 deg. In general, however, the experimental curves of the present investigation indicate that for such short lengths the movement of the initial axis of intersection of the cross strips, expressed in inches per inch length of spring strip, is dependent on the length of the latter.

This article applies to the 90-deg. symmetrical cross-spring pivots of sizes used in measuring-instrument design, of lengths up to $\frac{3}{4}$ in. and thicknesses up to 0·020 in. It has been found experimentally that the torque applied to the pivot is directly proportional to the angular rotation it produces; this statement applies to angular rotations up to 15 deg. to 20 deg., or to applied torques of 6 lb.-in., whichever is reached first. The experimental results show that the stiffness, i.e., applied torque per radian rotation, for a cross-spring pivot consisting of two pairs of cross springs, may be expressed by the formula:

$$\text{Stiffness K (lb.-in. per rad.)} = 4\,\frac{E' I}{(l + 0·035)},$$

where $E' = 27·5 \times 10^6$ lb. per square inch and I and l are expressed in the inch system of units.

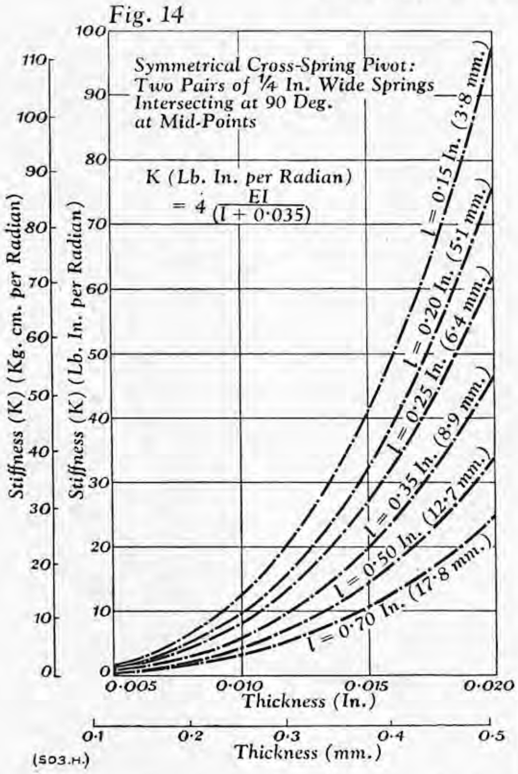
Curves of stiffness K, plotted on a base of spring-strip thickness for a variety of lengths, and calculated from the above experimental formula are given in Fig. 14, on page 476, for the benefit of designers. The experimental results also show that the movement, S, of the initial axis of rotation of the cross-spring pivot may be expressed by the formula:

$$S \text{ (in. per in. length of spring strip)} = (0·000357 - 0·000444\,l)\,\theta + (0·000055 - 0·000024\,l)\,\theta^2$$

where l is expressed in inches and θ in degrees.

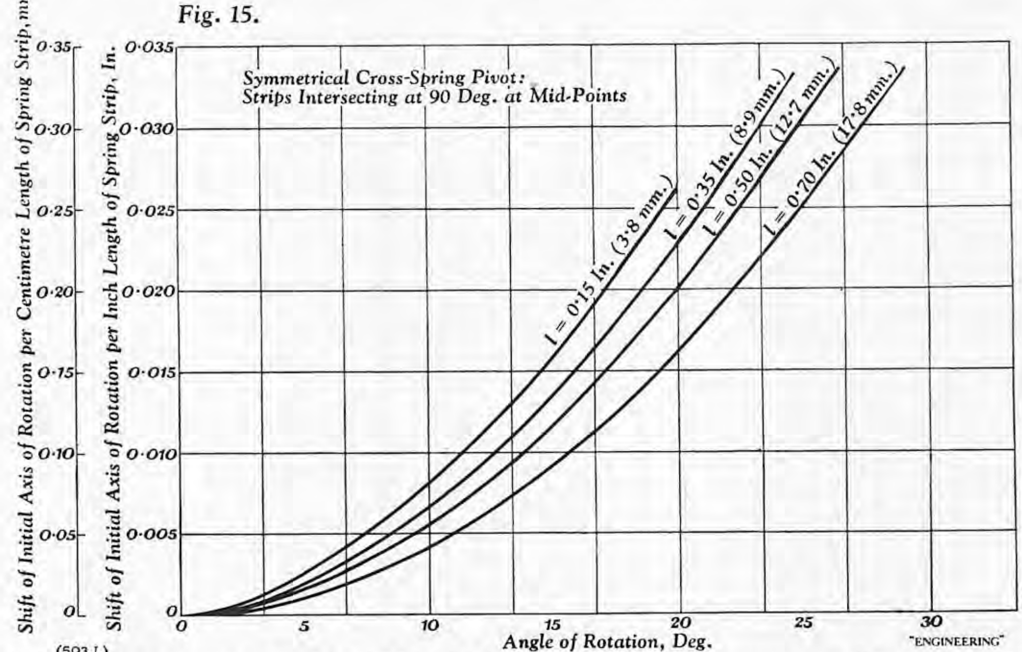
CHARACTERISTICS OF CROSS-SPRING PIVOTS.

Fig. 14



(503.H.)

Fig. 15.



(503.I.)

Curves based on the latter empirical formula, giving the relation between the movement of the initial axis of rotation and the angular rotation, are given in Fig. 15 for a variety of lengths of spring strip.

The authors desire to acknowledge the assistance afforded in some of the preliminary work by Mr. D. B. Spalding, and in the design of the adjustable cross-spring pivot by Mr. D. C. Barnes.

ASLIB ACTIVITIES.

This year there has been an important development in the work of Aslib, namely, the inauguration of groups of technical librarians and information officers from industry to foster the recording and distribution of scientific and technical information on their particular subject. At one of the sessions at the 26th annual conference of Aslib, which was held at Ashorne Hill, Warwickshire, from October 5 to 8, the formation of the first four subject groups—on economics, food and agriculture, textiles, and aeronautical engineering—was described by the group secretaries. The first three groups were initiated by Aslib; the idea of setting up an aeronautical information group, on the other hand, arose within the industry and was proposed to Aslib earlier this year.

The inaugural meeting of the Aslib aeronautical engineering group was held at the Royal Aircraft Establishment, South Farnborough, Hampshire, on Thursday, September 27. Approximately 100 representatives, from 46 different organisations, attended the meeting, and a committee was elected, the members of which represent the aircraft and engine constructors, the airways corporations, the Ministry of Supply, the College of Aeronautics, the Royal Aeronautical Society, and the technical Press. The chairman is Mr. R. G. Thorne, librarian of the Royal Aircraft Establishment. Three working parties were set up to consider abstracting services, the classification of aerodynamic data for the convenience of aerodynamicists, and the compilation of a union catalogue of the holdings of aeronautical libraries. It is intended that in the spring of 1952 an open meeting will be held to report on the work of the Group. We have been asked to state that any suggestions for consideration by the Group will be welcomed by the Group secretary, Mr. C. W. Cleverdon, College of Aeronautics, Cranfield, near Bletchley, Buckinghamshire.

Lectures on Power System Calculations.—An advanced course on "Power System Calculations for the Steady State" will be given at Heriot-Watt College, Chambers-street, Edinburgh, 1, on seven successive Saturday mornings from October 20, from 9.30 a.m. until 12 noon. The lecturers are Mr. F. H. Birch, Mr. R. K. Edgley, Dr. M. G. Say and Professor E. O. Taylor. The fee for the course is 2*l*. 2*s*. payable to the secretary of the College, from whom further particulars may be obtained.

BRITAIN'S FUEL PROBLEMS AND THE WORK OF THE FUEL RESEARCH STATION.*

By A. Parker, C.B.E., D.Sc.

The great progress that has been made during the last 250 years in many parts of the world in raising the material standard of living for an increasing population has been based largely on developments in the use of coal and petroleum to provide heat, light, and power to facilitate and supplement the labour of men and animals. Great Britain led the way in these developments, which have had a profound effect not only on the ways and standards of life, but also on human affairs generally.

Though records show that coal has been used in this country for at least one thousand years, at first gradually and then more rapidly replacing wood as a fuel, until about 100 years ago annual production was small in relation to the population. In 1700 the population was six or seven millions, and the output of coal was about 3 million tons, or only half a ton for each person. A century later, in 1800, the population had reached 10 or 11 millions, and the output of coal had risen to between 10 and 15 million tons, or roughly one ton for each member of the population, as shown in Fig. 1, opposite. By that time, the stage had been set for a great acceleration in mechanisation and industrialisation, with coal as the fuel and the reciprocating steam engine as the power unit. Our engineers and industrialists, with their inventive genius, skill and enterprise, led the world. By 1900 annual output of coal was about 220 million tons, the population had reached 37 millions, and the country had definitely moved over to dependence mainly on industry instead of on agriculture. Without these developments, Great Britain could not have supported so large a population. Manufactured products and coal were sold overseas to pay for imported food and raw materials, British-owned enterprises were established abroad, and London became the centre of banking and finance generally.

Industry continued to expand in Great Britain and annual output of coal continued to increase until 1913, when there was a record production of 287 million tons. Most of the coal was used at home, but there was a large surplus for export. During most of the Nineteenth Century there was no very great competition from abroad. By 1913, however, industry on a considerable scale had been developed in some other countries in Europe and America with good reserves of coal. The U.S.A. had also taken the lead in the production and use of petroleum. Competition had become keen. Coals of excellent quality were plentiful and could be obtained at a low price. The price was indeed too low, and little thought was given to the future. As a result, coal was used wastefully, causing widespread pollution of the atmosphere by smoke and grit and almost intolerable conditions in some industrial areas; and much low-grade but useful fuel was discarded in colliery dumps.

Then came the war of 1914-18. The demand for fuels of all kinds increased, but, for various reasons, including calls on manpower, annual production of coal in Great Britain fell from the 287 million tons of 1913 to 225 million tons in 1918, with an annual average of about the same quantity over the period 1919 to 1938. During the recent war, output of deep-mined coal dropped considerably and had to be supplemented by drawing from what might be classed as emergency reserves of open-cast coal. Even so, the total annual production in 1945 was down to only about 183 million tons, while home demand was increasing. Output has since been raised to 216 million tons in 1950, but home demand continues to increase, giving rise to difficulties at certain times of the year.

Coal is still being used with deplorably low efficiency for many purposes, though during the past 50 years there have been improvements in various directions. It is difficult to assess accurately the overall improvement, but it must have been appreciable. In 1900 inland consumption of coal was 160 to 170 million tons a year for a population of 37 millions, or roughly $4\frac{1}{2}$ tons for each person. Since that time there has been a great increase in mechanisation and in general industrial productivity, yet inland consumption has fallen to about 4 tons per person per year at a total of roughly 200 million tons for a population of 50 millions. It is realised that, in addition, home consumption of petroleum oils has risen in the same period from less than 1 million tons to more than 15 million tons a year, equivalent to 23 million tons of coal; but this oil is used largely for methods of land and air transport that were not extensively available at the beginning of this century.

It was during the 1914-18 war that this country first realised that ample supplies of fuel and power are of great importance in times of peace as well as war, and that there might soon be difficulty in obtaining the necessary supplies. Though our reserves of coal underground were considerable, they were not inexhaustible. We were drawing on the seams most easily accessible so that the difficulties of coal production were increasing. Further, we had no indigenous petroleum, and we might be faced with making large quantities of oil, even at high cost, from coal, or using coal in place of oil for purposes for which oil was far more suitable. There was urgent need to use coal and other fuels more efficiently and to investigate methods of making oil from coal. The Government accordingly decided to set up a central fuel research organisation under the newly-established Department of Scientific and Industrial Research. In 1917 a Fuel Research Board was appointed with the late Sir George Beilby as the first chairman and director of research.

Within two or three years, a central Fuel Research Station, equipped for fundamental work in the laboratory and for experiments with pilot plant and on a commercial scale, had been built at East Greenwich. The organisation was given the task of investigating, in the widest national interest, the nature, preparation, utilisation, and treatment of coals and other fuels, and of products derived from fuels. Within these wide terms of reference, the programme of work was planned to ensure a balance in fundamental and applied research to cater for long-term and short-term investigations, with arrangements for co-operation with universities and industry. It is interesting to note that two prominent items in the initial programme

* Paper presented at the Autumn General Meeting of the Institution of Heating and Ventilating Engineers, held in London on October 10, 1951. Abridged.

were the production of smokeless fuels, with the objects of improving fuel efficiency and of reducing pollution of the atmosphere by smoke, and the production of oil and chemical by-products in greater quantities from coal.

Since the establishment of the organisation about 30 years ago, the programme has been steadily developed, with periodic changes in emphasis on various items to meet changing needs. In addition to the main central Research Station at Greenwich, there is a small Scottish Branch at Thorntonhall, near Glasgow. The number of staff is now nearly 300, including about 70 graduates in chemistry, engineering, and physics, and 120 industrial workers.

It was soon realised by the Fuel Research Board that though there were estimates from geological investigations of the quantities of coal underground down to certain depths in the different coal-fields of the country, there was little systematic information on the physical and chemical properties of the coals in the many seams. Coals vary widely in characteristics not only from one coal-field to another, but also in the same coal-field and often in the same seam. One type of coal may be well suited for certain uses, but quite unsuitable for other purposes. For example, only certain coals can be used for the production of high-grade metallurgical coke. Some coals are of special value for the manufacture of town gas and others for producer gas. It is not always practicable to allocate coals solely from consideration of their special properties. Cost of transport, availability of supplies, and other factors must also be considered. It is impossible, however, to allocate our coals in the best national interest unless there is adequate information on what kinds of coal are available underground, where they are, in what quantities, and to what extent they can be economically worked.

The Fuel Research Board, therefore, early began a systematic physical and chemical survey of the nation's coal resources as they occur underground, and of the commercial grades as produced at the collieries. Survey laboratories were set up in all the principal coal-fields. By 1947, after the survey had been in progress for about 25 years, the number of staff employed in these provincial laboratories was about 90, and nearly 60 official Survey Papers had been published. In 1943 it was decided that sufficient information—though incomplete—had been collected to justify a beginning in extending the work to relate type of coal and quality to the quantity in reserve. The first simple evaluation of the data so obtained about the coals likely to be raised in the next 100 years was published in 1946 as Fuel Research Survey Paper No. 58.

In that paper a new system of classification was introduced that has since been adopted by the National Coal Board. It was concluded that, provided there is good planning of coal winning and intelligent allocation of the coals produced, there should not be a serious shortage of any one of the several broad types of coal underground within the next 100 years. It is particularly important, however, that coals of very special properties, such as those required for the highest grade of metallurgical coke, should be reserved as far as possible to meet the special needs; they should not be squandered by using them for purposes for which other more plentiful coals are equally suitable. As a result of the survey, there is more information about the coals of Great Britain than there is about the coals of any other country.

In this coal survey the work was not restricted to the usual physical and chemical examination, carbonisation assays, and fusion points of ash. Many samples were studied microscopically in very thin sections for such plant remains as spores and exines to assist in identifying and correlating seams. There were also determinations of minor constituents such as alkali chlorides, phosphorus, fluorine, and arsenic, and in many instances even rare elements such as vanadium, germanium, and gallium. Much of this more fundamental work is already proving of value; for example, germanium is now being extracted from dust deposits from particular uses of certain coals and is being used in the manufacture of self-amplifying crystal rectifiers.

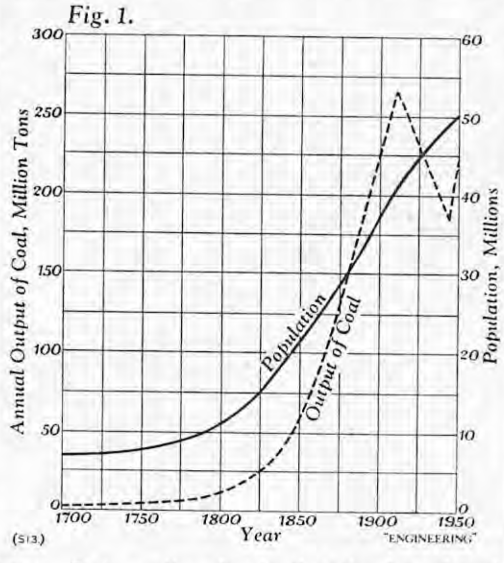
In 1947 the Coal Survey Laboratories were transferred to the National Coal Board, who have undertaken to carry on and extend the work and to continue the policy of publishing the results. In co-operation with the Board, the work at the Fuel Research Station on the minor constituents of coals is being continued.

Satisfactory systems of survey and classification of fuels and their products would be impossible without trustworthy methods of sampling and of physical and chemical examination of the required accuracy. Research programmes, commercial tests, and day-to-day control of industrial processes are also dependent on the reliability of methods of sampling and analysis. The Fuel Research Station has played a prominent part in devising new and improved methods, and in examining and correlating the work of others in this field. The accepted standard methods are based largely on the Station's work, and the staff take part in framing not only British but also international standards. In this work it has often been necessary to design and develop new equipment and apparatus. In the earlier stages of the development work, much of this equipment has been made in the Station's workshops and laboratories and tested also in other laboratories by co-operative arrangements. Later, firms have made the equipment for sale so that it would be more generally available.

Coal, as brought to the surface at the collieries, is not always in a form most suitable for the various industrial and domestic requirements. It has long been the practice at many collieries to grade the coal by screening into various sizes, to remove the larger pieces of shale and stone by hand-picking, and to remove smaller particles of incombustible matter by special processes of cleaning. As the more easily worked seams of coal become depleted, seams which do not so readily provide clean coal have to be exploited. Extension of coal cutting by machine and mechanical handling to reduce manual labour also increases the proportion of fine coal and the amount of dirt brought up with the coal. In consequence, the need for developing and applying satisfactory and economical processes of coal cleaning is increasing, especially methods of cleaning fine coal. In selecting the best methods of cleaning the different types of coal, account must be taken of the particular physical characteristics, especially the size and surface properties of the coal particles.

Until recently, laboratory studies of the physical properties of coals, followed by investigations to the scale of treatment of several tons an hour, have occupied a prominent part in the Station's work. The equipment included plants representative of several main types. It is worthy of note that the first plant in Great Britain for cleaning fine coal by vacuum froth flotation was erected at the Research Station. It was on a scale to treat 30 to 40 tons of coal a day and involved the use of wetting agents. The investigations were often continued at collieries in co-operation with the colliery undertakings. In addition, investigations have been undertaken on coals from overseas Commonwealth countries and Colonies, to assist those countries in exploiting their coal resources. There have also been investigations on de-dusting coals, and on the use of oils and wetting agents to reduce the dust nuisance in the handling and transport of coal; and there has been much work in studying and improving methods of "screen analysis" of sized coals and cokes and in drafting British Standard specifications on size analysis.

Fig. 1.



With the development of the scientific activities of the National Coal Board, the part played by the Fuel Research Station in this field of activity is being reduced. The Research Station now deals only with some of the more fundamental problems and with special investigations, such as the treatment of coals of different types from the Commonwealth and Colonies, and the production of specially-cleaned coal or anthracite for the manufacture of electrode carbon.

Large quantities of coal are destroyed or reduced in quality through fires resulting from "self-heating" of stocks in bulk storage at depots and works and in ships' bunkers. The mechanism of the "self-heating" from oxidation has been studied; and investigations on methods of storage to reduce the risk of fires have led to recommendations that are accepted as authoritative. The Station is frequently called on to advise on methods of storage and on combating fires that have developed.

Extensive investigations have been undertaken over a long period on the carbonisation of various coals, including some from overseas, at high and low temperatures to determine the effects of changes in conditions on the amounts and properties of the coke, gas, tars and oils, and other products. The work has covered the whole range of experiments from the laboratory to full-scale plant at the Research Station, at gas works, and with commercial installations of coke ovens. One achievement was the study and development of a process for the low-temperature carbonisation of coal to provide a smokeless solid fuel suitable for the domestic open fire. A commercial plant to the design of this system was erected and successfully operated for some years by an industrial undertaking in Yorkshire. Between the two wars, many processes were devised and developed to plants of commercial size, by groups and individuals, for the low-temperature carbonisation of coal. Fifteen of these plants have been thoroughly tested and the results have been published in official reports.

Within the last few years experiments up to the scale of treating 8 to 10 tons of coal a day have been carried out, with the object of ascertaining the possibilities of making relatively reactive coke suitable for the newer domestic appliances, by modification of processes of high-temperature carbonisation. It has been shown that under certain conditions of high-temperature carbonisation, even in plant similar to coke-ovens, cokes entirely satisfactory for the newer appliances can be produced. One important point is that the cokes should be of suitable grades of size.

An advanced stage has been reached in work in the laboratory and on a full scale on the manufacture of coke for blast furnaces and other metallurgical purposes. It has already been shown that entirely satisfactory coke for such purposes can be made by carbonising blends of coal of high coking quality with other coals that alone do not provide satisfactory coke. This work is being continued to cover a wide range of coals and blends. It is of great importance because the reserves of the best coking coals have been depleted more rapidly than the reserves of other coals, and difficulties of supply are increasing.

Systems of manufacture of producer gas and water gas from coals and coke and of carburetted water gas from coke and oil have been extensively studied from the stage of experiments in the laboratory to full-scale plant at the Station.

At the present time, experiments are in progress to ascertain the possibilities of several new methods that have been suggested for the complete gasification of coal and coke, particularly fine coal and coke breeze, for the manufacture of producer gas, water gas, and gas suitable for synthetic processes of making oil. These investigations include fundamental work on the flow of solids and gases and on heat transfer, in addition to the design and operation of pilot plants.

In relation to the underground gasification of coal, the literature on the work undertaken in Russia and in other countries has been critically surveyed and details of the work in Belgium, Italy, and the U.S.A. have been obtained. Visits have been made to Belgium to see the work on a small scale at the University of Louvain and on a large scale on a seam of coal near Liége.

Through the courtesy of the U.S. Bureau of Mines and the Alabama Power Company, a member of the Fuel Research Station staff has spent more than two years working with the team on the experiments on a large scale at Gorgas, Alabama. The Station is also represented on an Advisory Panel of the Ministry of Fuel and Power, which was set up to give scientific and technical guidance on work being carried out by the Ministry in co-operation with the National Coal Board on several selected seams of coal. In addition, experiments on a small scale with blocks of coal have been carried out at the Research Station at Greenwich. The problem is not an easy one to solve, and several difficulties will have to be overcome if a satisfactory method at reasonable cost is to be developed.

(*To be continued.*)

Quality in Mass Production: Inspection Team Visiting United States.—In order to study methods of inspection practised in United States plants engaged in mass production, a team of eight specialists sailed in the Mauretania on Tuesday, October 9. The team is led by Mr. Leonard Sollis, managing director of the Highfield Gear and Engineering Co., Ltd., Huddersfield, and the joint secretaries are Mr. E. D. van Rest, of the National Physical Laboratory and the Ministry of Supply, and Dr. John Barnett, of Thorn Electrical Industries, Enfield. The other members are Mr. A. Heward of W. and T. Avery, Ltd., Mr. C. H. Johnson, of Hoover Ltd., Mr. S. W. Nixon, of the Rover Co., Ltd., Mr. F. J. Mills, of James Booth & Co., Ltd., and Mr. P. R. Snadden, of the British Thomson-Houston Co., Ltd. Following the normal procedure established by the Anglo-American Council on Productivity, the team have been touring works in this country during the few days before departure. In the United States they hope to examine inspection methods applicable to raw materials, semi-raw materials and finished articles.

A REVIEW OF HIGH-SPEED HYDRODYNAMIC DEVELOPMENT.*

By Ernest G. Stout, B.S.M.E., A.F.I.Ae.S.

(*Concluded from page* 442.)

As already stated, the U.S. Navy was interested in developing a high-performance seaplane with propeller turbines for operating from forward-area bases for protracted periods. Convair submitted a proposal for such an aircraft in April, 1946, and by December of that year flight testing had started on the radio-controlled dynamic model of the new design. This model made more than 2,000 test runs and completed the full hydrodynamic flight-test programme scheduled for the full-scale aircraft three years later. The seaplane was designated the XP5Y-1 and is shown in Fig. 12 on its first flight in April, 1950. Immediately apparent is the long hull (length-to-beam ratio of 10) and the resulting clean lines. Initial flight tests confirmed the results of the model tests very closely. In fact, the hydrodynamic characteristics were of sufficient excellence to justify flying the aircraft at its design gross weight on its seventh flight, at which time it established the world's endurance record for turbo-propeller aircraft, and on the eighth flight the take-off was at the design overload.

The actual performance figures for the P5Y aeroplane are still secret, but they are comparable in many respects with typical piston-engined fighters of the second World War. The multi-cellular watertight method of hull construction was incorporated in the P5Y aircraft. By proper distribution of floodable length the cargo floor is parallel to the static water line, free of discontinuities and continually above the critical flood heights. The inhabited interior of the hull is completely free from all obstruction, allowing straight-through loading of large items and complete accessibility, as in the best land-based aircraft.

In the adaptation of transonic aircraft design to water-based operation, it appeared logical to start with an ideal aerodynamic layout, and by extensive hydrodynamic research to develop new principles and applications which would give the same degree of seaworthiness and stability associated with the best hulls of conventional form.

The basic "in-flight" configuration must consist of a smooth, unbroken form, of high critical Mach number throughout. In order to secure elementary flotation it would be necessary to supply sufficient volume of body so that engines, air intakes, jet exhausts and personnel would not be inundated. This led logically to the blended wing-hull configuration.

The first step was to select a desirable transonic swept-wing plan-form and thickness ratio. The centre portion was gradually thickened to a maximum at the centre line to provide the required body depth for flotation. So that this volume could be most efficiently used the major portion was displaced below the normal chord plane. The desired aerodynamic thickness ratio was maintained through the centre section by increasing the chord in direct proportion to the increased thickness.

It was determined that straight transverse and buttock sections could be employed in the floating body without altering the critical Mach number of the form. This provided a good planing section of adequate dead-rise to absorb the water loads incident to high-speed operation on the water; by virtue of the increased chords required in the region of thickness transition, adequate planing length was provided for good hydrodynamic operation. As a result of these geometric considerations this elementary floating body, by reason of its inherent low centre of gravity and high water-plane inertia, would float upright on the water surface without recourse to wing-tip floats.

With a fundamental set of lines available for a blended-hull configuration that satisfied the requirements for transonic flight and elementary floatation, the Convair Hydrodynamics Laboratory was in a position to construct a series of dynamically similar models for evaluating the inter-related parameters of hydrodynamic sustentation. Fig. 13 shows a typical set of blended lines and offsets which formed the starting point for the hydrodynamic research programme; it will be noted that it is difficult to draw any sharp line of demarcation between the hydrodynamic and aerodynamic functions. Since the model must be dynamically similar to an actual prototype design, it was necessary to prepare a complete preliminary design, including crew accommodation, fuel and tactical equipment for each configuration to be investigated.

The principal hydrodynamic studies to be carried out consisted of water separation and control at the boundaries of the planing surfaces, such as the chine and step (to use conventional terminology), followed by more detailed studies of hydrodynamic stability during take-off and landing, water-looping, low-speed manœuvrability and similar characteristics. This programme was designated the "Skate Project" and consisted of nine basic evaluations.

As the bottom of a blended-hull is not bounded by predetermined discontinuities, considerable latitude existed for the optimum selection of planing surface proportions. It was possible to vary the nominal beam, and hence the length-to-beam ratio, between broad limits by appropriately selecting the location for the retractable spray dams. A typical blended-hull form is shown in Fig. 14, compared with an appropriately-scaled view of the XP5-1; the critical spray clearance, which in the conventional hull is determined by the propeller, is nearly the same. In order to facilitate retraction it is desirable to locate the dam on a straight element of the planing surface and to run it well forward. For best results it should be so located vertically on the hull that approximately one-third of its length to the centre of buoyancy is out of the water at static rest. Due to the broad flare of the after-body, it was found that the bottom pressures were dissipated to such an extent that the tail spray was practically non-existent; there was no necessity for carrying the spray dam aft of the step. However, to prevent span-wise spread of the after-body water, it was desirable to incorporate a fixed chordwise fence at the inboard end of the ailerons. The depth of the dam appeared to be largely independent of aeroplane size as long as it broke the planing surface with a sharp angle and penetrated the flow sufficiently to generate a strong jet. In most

* Paper presented at the Third Anglo-American Aeronautical Conference at Brighton on September 5. Abridged.

HIGH-SPEED HYDRODYNAMIC DEVELOPMENT.

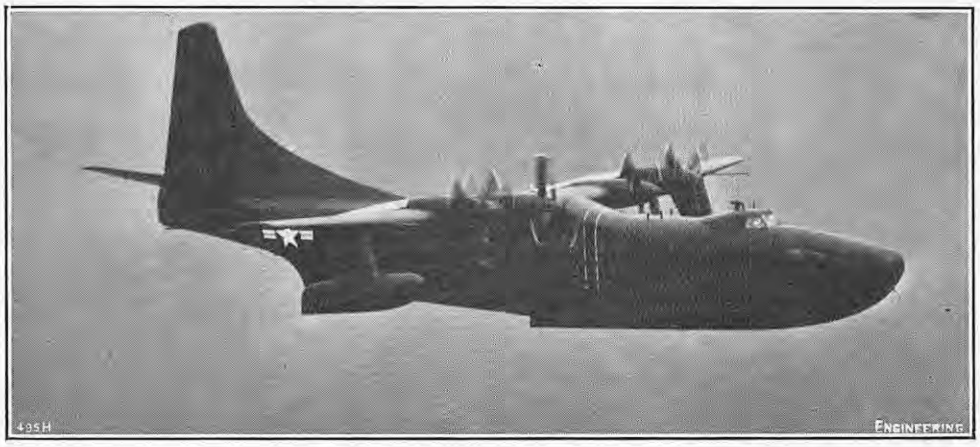


Fig. 12. "Convair" XP5Y-1 Propeller-Turbine Flying Boat.

Fig. 13. TYPICAL HULL LINES FOR A TRANSONIC BLENDED-HULL CONFIGURATION.

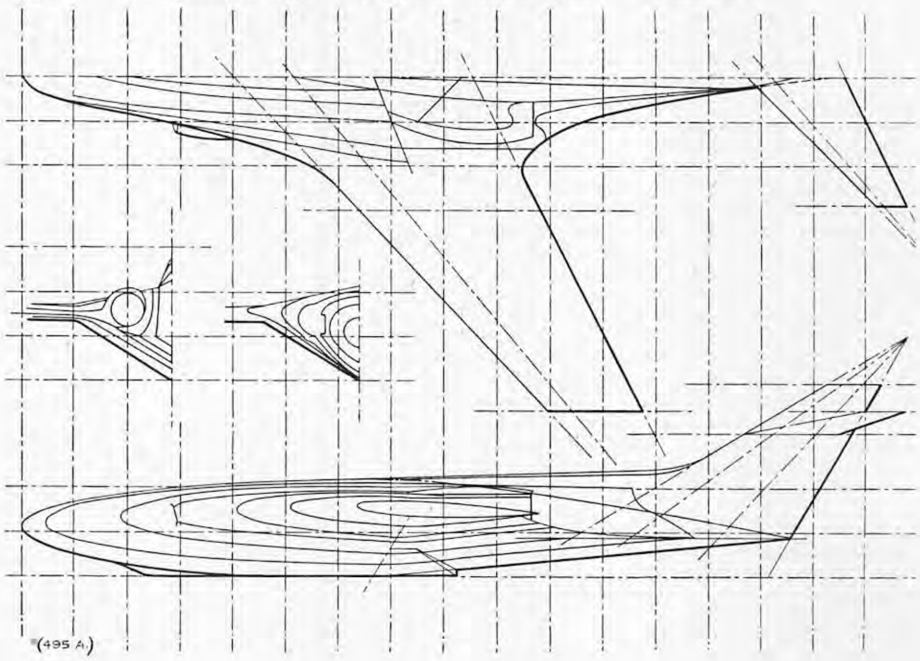
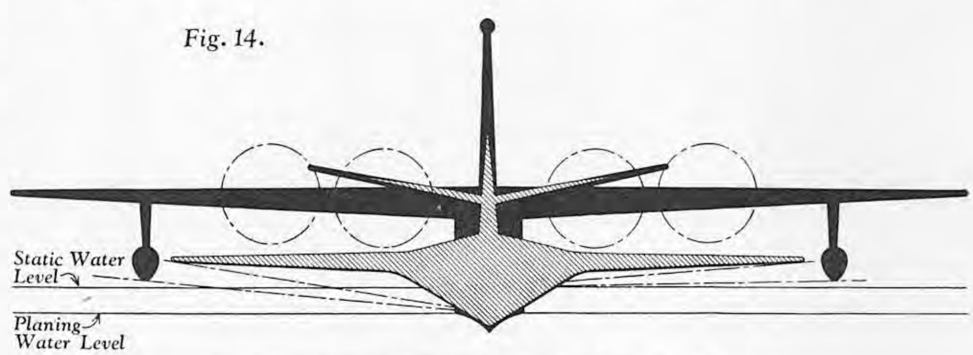


Fig. 14.



	Static Angle of Heel, Deg.	Planing Angle of Heel, Deg.	Planing Clearance, Ft.
Skate	5·50	10·00	5
XP5Y-1	2·50	6·50	3

(495 K) "ENGINEERING"

HIGH-SPEED HYDRODYNAMIC DEVELOPMENT.

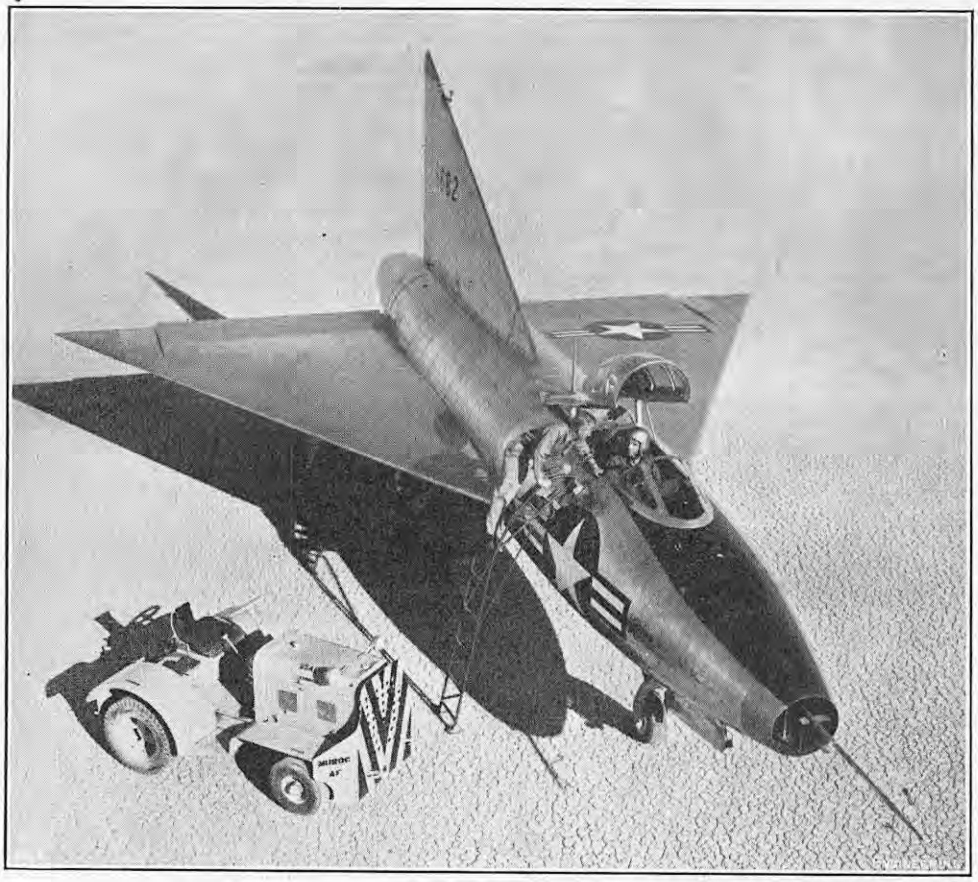


Fig. 15. "Convair" XF-92A Delta-Wing Aeroplane.

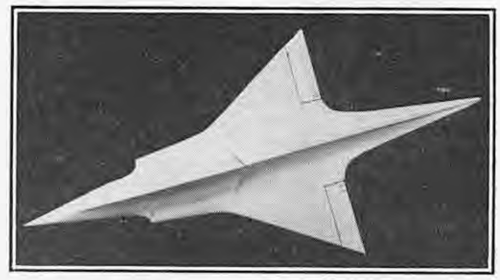


Fig. 16. Dynamically-Similar Delta-Wing Blended-Hull Model.

cases a full-scale dimension of 5 in. or 6 in. was sufficient.

The step is retractable and is unique only in that it must receive forced ventilation as it has no access to the atmosphere at the chine. Air requirements were found to be moderate and were obtained from a small forward-opening scoop on the deck which fed a plenum chamber in the step well. A 45-deg. plan-form step was found to be most desirable, with an extended depth at the keel of 9 to 10 per cent. of the width. The step plates were hinged at the lower flange of the rear wing spar and formed an element of the after-body in the retracted position. Extreme care was necessary to ensure that the elements of the step plates, in the extended position, faired with the straight buttocks of the fore-body because any discontinuity in this region resulted in severe porpoising.

The influence of linear warping of the fore-body was investigated; as for conventional hulls of high length-to-beam ratio, no curvature in the fore-body buttocks can be tolerated for a region at least 1½ beams forward of the step. With adequate ventilation air supplied to a step of sufficient depth, excellent take-off and landing stability can be obtained for any blended-hull configuration, such as have rarely been attained in any configuration of conventional design.

The conventional seaplane, with its high centre of gravity, is inherently unstable in roll; this condition is aggravated in rough-water operation. Statistics show that a majority of water-loops experienced in such aircraft may be attributed to the float burying in waves, at high water speeds, as a result of uncontrolled roll. The blended-hull configuration has its centre of gravity below the metacentre, i.e., it has ship stability; consequently its tendency to roll under identical conditions of wind and sea will be considerably less than in the conventional seaplane. Moreover, an appreciably higher angle of roll is required to bring a rigid portion of the Skate wing into the water, compared with the conventional float position. Extensive catapult landing studies of blended-hull designs, up to roll and yaw angles of 20 deg. have demonstrated no tendency to water-looping.

Considering a typical twin-engined fighter-bomber, with a gross weight of approximately 40,000 lb., the transonic high-speed and dive requirements necessitated a thin wing and moderately high sweep-back in order to minimise the effects of compressibility on the aerodynamic characteristics. A wing loading of approximately 45 lb. per square foot, and the aeroplane size, were chosen to give moderate take-off and landing speeds and to accommodate the fuel required for a reasonable range. Considerations of structural weight, fuel for cruise, and water clearance, led to the selection of an aspect ratio of 4·0 and a taper ratio of 2·5 to 1. A wing section with favourable pressure distributions for high speed and a relatively large leading-edge radius with good stalling characteristics was used on the entire outer wing panels and blended into similar sections used to develop the basic hull shape. A sweep angle of 40 deg. at the wing quarter-chord line was determined to be the most satisfactory compromise between compressibility and adverse effects of sweep with respect to lift, stability and control. Short-span conventional wing flaps and leading-edge slats were provided to give satisfactory landing and take-off speeds with freedom from tip stall.

An all-movable horizontal tail was selected, rather than the usual elevator control, to minimise the trim changes through the transonic speed range. The lower thickness ratio of the aerofoil section chosen for the tailplane, combined with 41 deg. of sweepback, resulted in a higher critical speed than that of the wing. Lateral and directional control was provided by conventional ailerons and rudder; and, like the horizontal control, was assumed to be power-operated. Complete wind-tunnel evaluation of a model representing this configuration substantiated all of the anticipated requirements for drag, lift, stability and control. From these results it was determined that a Mach number of the order of 0·95 could be achieved, in level-flight with a hydrodynamically proved water-based aircraft.

Studies have been initiated to investigate the basic parameters of water-based supersonic aircraft. The fundamental hydrodynamic problem is the extension of basic planing theory and impact alleviation to much higher water-speeds than considered heretofore. Once again, the first step in the preliminary study was to select an aerodynamic configuration of the desired characteristics.

A study programme of delta wings was initiated by Convair in 1945, and a tailless 60-deg. delta-wing layout was adopted for a tactical landplane, the XF-92, which was to have an unorthodox power plant. Work was started late in 1946 on a full-scale flight-test version known as the XF-92A, illustrated in Fig. 15, which had a conventional turbo-jet engine. Since September, 1948, the XF-92A has been undergoing extensive flight testing at Muroc and has established excellent correlation between theoretical predictions, model and full-scale. In view of this experience it was natural that the delta layout should be employed in the supersonic hydrodynamic-research programme.

The blended hull was selected for the preliminary studies. The dynamic flying model, illustrated in Fig. 16, shows the blended hull applied to a 60-deg. delta wing. To allow for the increased impact loads due to a higher take-off speed, the dead-rise was increased to give the same structural load required for conventional design. With the power loadings that will be available, high dead-rise hulls hold out great promise for successful rough water operation at high planing speeds. A wind-tunnel model indicated that the desired aerodynamic cleanliness and performance were attainable.

It is possible that the supersonic approach that has been discussed is not the most desirable solution to the problems. It is presented more as an example of the line of thought that will provide such a solution, rather than the fact. It is not too early to give high-speed water-based aircraft serious consideration in strategic planning.

TRADE PUBLICATIONS.

Cupola Meters.—A booklet issued by the Metronic Instrument Co., Ltd., Ettingshall, Wolverhampton, and entitled "How to read the Cupola Meter," gives details of cupola-blast indicating and recording instruments manufactured by the firm, together with hints on interpreting meter indications and securing optimum results in blast-furnace operation.

Diesel Engines for Oil-Well Drilling.—Davey, Paxman & Co., Ltd., Colchester, have issued a booklet, No. 1246, on the "Package" Diesel units they make for use with oil-well drilling rigs. The power of the engines ranges from 98 to 725 h.p. Each "Package" set consists of the engine, a radiator for the water and oil, control gear, canopy, air-intake filters, starting equipment, instrument panel, etc., all mounted on a skid-type base.

Prestressed-Concrete Construction.—The Magnel-Blaton prestressed-concrete system is described in a booklet issued by Stressed Concrete Design, Ltd., 54, South Side, Clapham Common, London, S.W.4, who are the licensees for the United Kingdom and the Commonwealth (except Canada). The post-tensioning system is described in some detail, examples of structures using the system are illustrated, and drawings of the standard parts, etc., are given.

Electrodes and Plant for Manual and Automatic Arc Welding.—A catalogue received from the Quasi-Arc Co., Ltd., Bilston, Staffordshire, gives illustrated details of the range of electrodes, plant and accessories manufactured by them for automatic and manual arc welding. Advice is given on the choice of electrodes for particular purposes and the firm's new single-operator arc-welding transformers and the Unionmelt process for submerged-melt automatic arc-welding are described.

Hiduminium Extrusions.—High Duty Alloys, Ltd., Slough, Bucks., have prepared a comprehensive book on their Hiduminium sections, which include bars, angles, channels, I and H beams, T-bars, tubes, anchor sections, and window and architectural sections. The principal physical characteristics are given, for example, size, weight per foot, sectional area, moments of inertia, moduli of section, and radii of gyration. There are also various general tables, an introduction on the extrusion process, and a pictorial index to the sections.

Germanium Crystal Rectifiers.—The Westinghouse Brake and Signal Co., Ltd., 82, York Way, King's Cross, London, N.1, have published a pamphlet giving particulars of the wide range of germanium crystal rectifiers recently introduced by them. These rectifiers are of hermetically-sealed ceramic construction and are ½ in. long by $\frac{3}{16}$ in. diameter. The upper limit of the peak working voltage is 100 volts, and of the forward current 50 milliamperes. Characteristics and curves of all types are given, and a table shows which type should be selected for 16 applications.

NOTES ON NEW BOOKS.

Cofferdams.

By L. WHITE and E. A. PRENTIS. Second edition. Columbia University Press, New York, U.S.A. [Price 10 dols.]; and Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4. [Price 63s. net.]

THE publication of a second edition of this book ten years after the appearance of the first edition provides a reliable measure of its value when account is taken of the rather specialised nature of the subject. This edition is somewhat larger than its predecessor, though the general scope remains unaltered. The aim has been to improve the volume as a practical working treatise, with sufficient explanation in discussing the principal factors that influence the various methods of design and construction. The new subject matter includes constructional details of three cofferdams on the River Mississippi: one on rock, one using well points, and a circular steel-sheeted type with reinforced-concrete wales. As previously, the authors discuss each scheme from the point of view of engineers with long and varied experience in the construction of such works, as may be indicated by reference to another new section, on a cellular cofferdam constructed at Sault Ste. Marie, Michigan, in 1944. Many students will read with profit of how the authors' firm of contractors carried out this work in war time, with difficulties in the scarcity of necessary materials; why, in making the closure, great care had to be exercised in driving the sheeting, and several other points of interest. The young civil engineer soon realises why each case requires separate consideration, as in the land cofferdam on a site for new foundations of a large store, bounded by city streets on three sides, the fourth abutting on part of the existing store that was to remain in service until the new building was completed. The additional illustrations and data on the wage rates per hour paid for particular classes of work at Lock No. 27 on the River Mississippi, Granite City, Illinois, in 1949, are other indications of the revision which has been undertaken to bring the book up to date in details as well as in general principles.

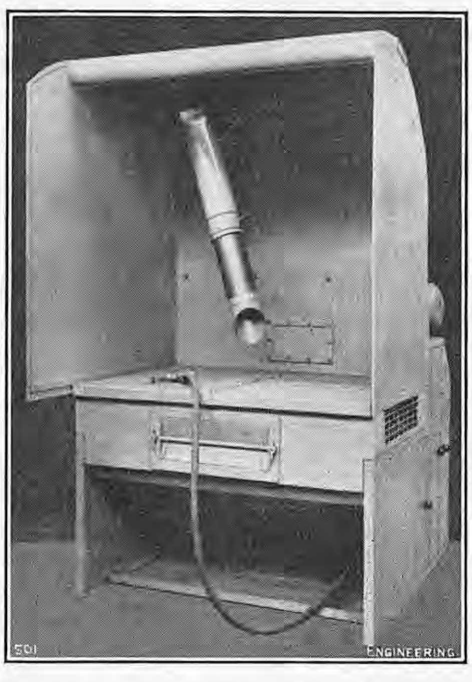
Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations.

Fourth edition. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 3s. net.]

REGULATIONS for the generation, transformation, distribution and use of electrical energy in premises coming under the Factory and Workshop Act, 1901, were first made by the Secretary of State in 1908. In view of their complexity these regulations were accompanied by an explanatory memorandum prepared by the then Senior Electrical Inspector. This document has been revised from time to time, but, as the most recent version is now 27 years old, something rather more modern is required. This is the more necessary as, in the interim, the use of electricity has been extended to a number of additional processes and, under the Electricity (Factories Act) Special Regulations, 1944, factories, electrical stations, warehouses, docks, ships when worked in dock, building operations and works of engineering construction all come within the scope of the regulations. In general, it may be said that there has been no change in the regulations themselves. Regulation 18, which deals with the requirements for switchboards working at high pressure or extra-high pressure has, however, been amplified by notes on the locking of shutters, doors and screens over live conductors; these switches are remotely operated. It may be necessary to earth the main frame as well as the handle, since joints in mechanical linkages cannot be relied upon to give the necessary continuity for earthing purposes. Paragraph (*d*) of this regulation, which lays down that a high pressure or extra-high pressure switchboard must, generally speaking, be made dead before any work is done upon it, has been redrafted to remove a difficulty in interpretation to which attention was called in the High Court. The relevant comments have therefore had to be re-written. The regulation requiring all conductors to be insulated, protected, placed and safeguarded to avoid danger has had to be amended, owing to the availability of new materials. It is also laid down that manually-operated circuit breakers should be of the loose-handle type with reliable "on" and "off" indications, and that all switches and circuit breakers should have a sufficiently strong bias towards the open position to ensure that they cannot remain partly closed. The use of high rupturing capacity cartridge-type fuses is recommended and it is suggested that circuit breakers with ratings exceeding 150 MVA should not be directly hand operated. This memorandum should be in the hands of all those responsible for installing and maintaining electrical equipment in those places to which the regulations now apply.

MAGNESIUM-ALLOY DUST COLLECTOR.

IN machining components manufactured from magnesium alloys, special precautions have to be taken in the disposal of the inflammable and explosive dusts produced. To comply with the stringent regulations laid down by the Factories Act, Messrs. Dallow Lambert and Company, Limited, Spalding-street, Leicester, have developed a series of unit dust collectors, distinguished by the name Multiswirl, for use with grinding and polishing machines. Air laden with magnesium-alloy dust is drawn through a specially-designed duct and is thoroughly immersed and scrubbed in a water chamber. To ensure that the operator cannot use his grinding or polishing machine unless the dust collector is working efficiently, the electrical circuit of the motor driving the machine is interlocked with an airflow-operated switch within the fan chamber and with a float-operated switch in the water chamber. Thus, if for any reason the velocity of the air flow falls below the value required for efficient dust collection, or if the water level is too low for adequate scrubbing of the dust, the motor circuit is broken and the machine cannot be operated until the correct air-flow or water level has been restored. A delay switch in the main circuit ensures that the machine cannot be started until the dust-collector fan has been running for five minutes,



in order to remove any gases which may have accumulated during the rest period. Explosion releases are also fitted.

Three types of Multiswirl unit are available. The bench unit comprises a series of plastic-covered rollers, $\frac{3}{8}$-in. apart, on which the workpiece to be ground is placed; the heavy dust particles fall through the spaces between the rollers into the water chamber below and the light floating dust is drawn by suction through a telescopic universal duct fitting. Another type of dust collector has been designed for double-end polishing spindles, which are mounted on the unit itself; it is provided with Dallow Lambert Mark II polishing hoods in place of the covered rollers and the telescopic fitting. The third type of dust-collector unit, shown in the accompanying illustration, is similar to the bench unit, but is provided with a booth in which the telescopic fitting is mounted; the latter can be moved by the operator to any position. The booth is provided with strip lighting and is designed for easy cleaning and maintenance.

PETROLEUM INDUSTRY EXHIBITION.—An exhibition covering the scientific, technological and other aspects of the petroleum industry, held in recent months at the Universities of London, Glasgow, Leeds and Cambridge, has been so well attended that it has been decided to show it in three other centres. The fifth showing of the exhibition opened at the Museum and Art Gallery, Leicester, on October 8 and will continue until October 27. It will then go to the Firth Hall, University of Sheffield, from November 8 to 17 and, from there, it will move to the Royal Scottish Museum, Edinburgh, where it will be on view from December 17 until January 27, 1952. The exhibition is sponsored jointly by the Shell Petroleum Co. and the Anglo-Iranian Oil Co., Ltd. We understand that oil companies operating in France, Belgium and the Netherlands are planning similar exhibitions.

BOOKS RECEIVED.

Basic Road Statistics. Great Britain. 1951. British Road Federation Limited, 4A, Bloomsbury-square, London, W.C.1. [Price 1s.]

Electricity in Transport Over Sixty Years' Experience. 1883-1950. The English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2. [Price 12s. 6d.]

British Commonwealth Scientific Official Conference. Report of Specialist Conference on Fuel Research. London, July, 1950. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 9d. net.]

University of Illinois. Engineering Experiment Station. Circular Series No. 62. *Preparing Technical Material for Publication.* A Manual for Authors of College and Station Publications. By LISLE A. ROSE, PROFESSOR ELMER F. HEATER and GEORGE R. FOSTER. The University of Illinois Engineering Experiment Station, Urbana, Illinois. [Price 60 cents.]

University of Illinois. Engineering Experiment Station. Bulletin Series. No. 388. *Cleavage Fractures of Ship Plates.* By PROFESSOR WILBUR M. WILSON, ROBERT A. HECHTMAN, and PROFESSOR WALTER H. BRUCKNER. [Price 1 dol.] No. 389. *An Evaluation of the Hardening Power of Quenching Media for Steel.* By EARL J. ECKEL, ROSS M. MAYFIELD, GLEN W. WENSCH, and FRANK A. ROUGH. [Price 1.50 dols.] No. 391. *Radiant Baseboard Heating and Effects of Reduced Thermostat Setting and Open Bedroom Windows at Night.* By PROFESSOR WARREN S. HARRIS and ROBERT H. WEIGEL. [Price 70 cents.] No. 395. *Almost Sinusoidal Oscillations in Nonlinear Systems.* Part I. *Introduction—Simultaneous Oscillations.* By PROFESSOR JOHANNES S. SCHAFFNER. [Price 60 cents.] The University of Illinois Engineering Experiment Station, Urbana, Illinois.

Hydraulic Transients. By DR. GEORGE R. RICH. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 6 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 51s.]

Introduction to Heat Transfer. By PROFESSOR AUBREY I. BROWN and SALVATORE M. MARCO. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 4·50 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30s.]

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

Gas Turbine Theory. By H. COHEN and G. F. C. ROGERS. Longmans, Green and Company, Limited, 6 and 7, Clifford-street, London, W.1. [Price 30s. net.]

Combustion, Flames and Explosions of Gases. By DR. BERNARD LEWIS and DR. GUENTHER VON ELBE. Academic Press, Incorporated, 125, East 23rd-street, New York 10, U.S.A. [Price 13·50 dols.]

Intermediate Dynamics and Statics. By S. L. GREEN. University Tutorial Press Limited, Clifton House, Euston-road, N.W.1. [Price 12s. 6d.]

Technical Sketching. By E. F. WALLER. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 6s. 6d. net.]

Encyclopædia of Oxy-Acetylene Welding. By L. J. TIBBENHAM. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 10s. 6d. net.]

A New Approach to Engineering Tolerances. By J. GILSON. The Machinery Publishing Company, Limited, National House, West-street, Brighton, 1. [Price 10s. 6d.]

Milling Cutter Production and Calculation. Machinery's Yellow Back Series No. 29. The Machinery Publishing Company, Limited, National House, West-street, Brighton, 1. [Price 3s. 6d.]

L'Avventura della Eritrea. By MARINO IANNUCCI. "Rivista Marittima," via S. Andrea delle Fratte 1, Rome, Italy. [Price 500 lire.]

Berechnung mechanischer Schwingungen. By PROFESSOR FRITZ SÖCHTING. Springer-Verlag, Mölkerbastei 5, Vienna 1, Austria. [Price 56s.]

Einflussfelder elastischer Platten. By PROFESSOR ADOLF PUCHER. Springer-Verlag, Mölkerbastei 5, Vienna 1, Austria. [Price 47s. 6d.]

Gas Discharge Lamps. Principles, Characteristics, Applications. By J. FUNKE and P. J. ORANJE. N.V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. [Price 16 florins, or 30s.]

National Physical Laboratory. Test Pamphlet No. 7. *Tests of Standards of Length and Angle.* The Director, National Physical Laboratory, Teddington, Middlesex.

Electrodeposited Tin-Nickel Alloy Coatings. By N. PARKINSON, S. C. BRITTON, and R. M. ANGLES. Tin Research Institute, Fraser-road, Greenford, Middlesex [Gratis.]